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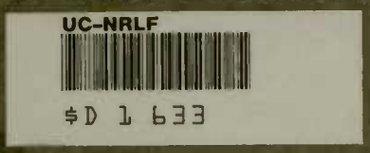

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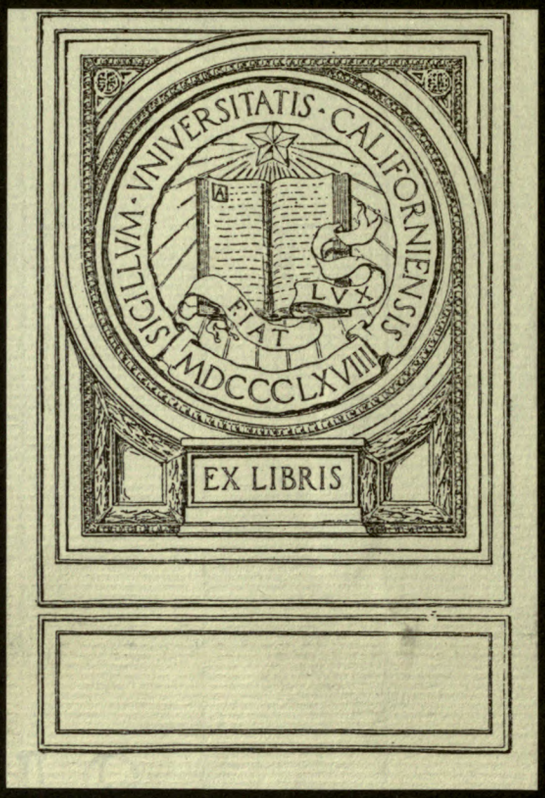
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MODERN TELEPHONE ENGINEERING

Lecture delivered before the New York Electrical Society

February 14, 1901

BY

KEMPSTER B. MILLER

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MODERN TELEPHONE ENGINEERING*

BY

KEMPSTER B. MILLER

Mr. President and gentlemen of the New York Electrical Society:

The subject which you have assigned to me, "Modern Telephone Engineering," is one of such breadth that only portions of it can be treated in a single evening, and those portions not with as great an amount of detail as I would desire.

After careful consideration, I have concluded that the subject matter which is most likely to interest the greatest number of those present is a discussion of a few of the engineering problems arising in planning a telephone exchange, and also a description of some of the methods and means employed in what may be considered modern telephone practice. Time will not permit me to deal with the various items in detail, and therefore these remarks should be regarded in many cases rather as suggestions than as complete treatments of the various points.

The statements which I will make in the course of the evening will relate to what I believe to be good telephone practice, regardless of whether it is the practice of the Bell or of the independent companies. The circuits shown are those of the Bell Company, and the apparatus mostly that of the Kellogg Switchboard & Supply Company, with which company I am connected. I trust that I may be pardoned for appearing partial to the apparatus of this latter company; but, in the first place, my brethren under the wing of the Bell Company have not exhibited an undue amount of enthusiasm in the matter of furnishing me with cuts and data thereon. In the second place, I have been closely identified with the design and the manufacture of the Kellogg apparatus and am therefore better able to talk of it. In the third place, I think that most of the telephone engineers here are perhaps as familiar, if not more so than I am, with the apparatus of the Bell Company, and therefore will be more interested in that of another make. Be this as it may, whatever methods, circuits and apparatus are described will be typical of the telephone art as it exists to-day.

The first problem arising when a telephone exchange is to be installed in a large city is that of the number, size and location of the central office or offices. The proper solution of this problem depends in all cases upon local conditions and can be attained only after much consideration and calculation.

If the cheapest were the best, the telephone engineer would experience comparatively little difficulty in exactly determining the location of the telephone office or offices, as well as the boundaries of the office districts in any city, after having canvassed the communities and ascertained the topographical location of the present and prospective subscribers. The most important consideration is that of the quality of service to be rendered. This factor, "quality of service," can not be expressed in dollars and cents; it must be left to the good judgment of the engineer to so construct the telephone plant that the demands made by the public are satisfied without making the plant so expensive as to be an unprofitable investment.

Other matters to be considered in the preliminary lay-out of a system are:

Annual cost of operation, including salaries of operators and the cost of current supply; fixed charges and rent, interest and depreciation on the office equipment, interest and depreciation on the wire plant, interest and depreciation on the subscribers' apparatus, and annual cost of maintenance. These factors, unlike the first mentioned, are subject to predetermination with a fair degree of exactness.

A brief discussion of each of these various factors as to their bearing on the number and location of offices will probably be of interest.

I think it is a well established fact that the best telephone service can be given where all the lines of the subscribers in a city run to a single exchange and are there handled by a single multiple switchboard. By this means all calls for connections by any subscriber may be handled by a single operator. Where the number of subscribers, however, is too great to be connected to a single switchboard, or where the distribution is such as to naturally group them about well defined and remote centres, a greater number than one exchange must be installed and lines provided between them for connecting the subscribers in the different exchanges. Such lines are called trunking lines, in distinction to subscribers' lines, which connect the subscriber with the central office.

In most cases where trunking is necessary, most calls have to be trunked. I believe the percentage of trunked calls to total calls for Greater New York is in the neighborhood of eighty. A connection made over a trunk line necessarily occupies more time and thereby renders the service a little slower. In fact, the aggregate time required for connection over a trunk line is practically twice as great as where accomplished by a single operator in a multiple board. The fact that two operators necessarily handle a trunk connection necessarily increases the liability to error in making the connection, and therefore produces less satisfactory service. The trunking apparatus and circuits, in order not only to transmit speech, but to convey the requisite signals between the operators, are necessarily more complex than subscribers' line circuits, and thereby a greater liability to trouble exists than where no trunks are required.

So far, therefore, as the question of quality of service is

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concerned, there can be no question but that a single large office serving all of the subscribers in a given city is best.

Again, if we consider only operating expense, a single office serving the entire city is best. First, because in a single office the total number of operators required is a minimum (it has been amply proven by experience that this is so); second, in a trunking system the number of higher paid persons than operators will be greatly increased, as there will be for instance, a manager, a wire chief, a chief operator, etc., for each of the different offices; third, the item of current supply is naturally higher with several offices than with a single large one, as the power system requires more current on account of the greater amount of apparatus and also on account of the machinery being split up into smaller units and working with less efficiency.

The item of fixed charges and rent includes the salaries paid to the general management, the business and engineering offices, as well as rent. The former items should not differ materially whether one office or a greater number is used. The question of rent, however, is a little more complex and must be accurately determined for each particular city. It will vary from 50 cents to $2 per annum for every square foot of floor space. Where a single office is used this is necessarily located somewhere in the center of the city where rent is highest. Where a number of offices are used, the offices will not be in the center of the city, but will of necessity be at points densely populated. The probabilities are that the rental, which will also include light, heat, elevator service and janitor service, etc., will be slightly cheaper for a large office located in the heart of the city than for several smaller offices located in the most densely populated portion of their respective districts.

The interest and depreciation on the office equipment is in most cases smaller for the single office system, for while it is true that a single large multiple board costs more than a number of smaller multiple boards having the same aggregate capacity as the large one, yet the addition of the trunking apparatus to the smaller boards, and the fact that the power plants, managers, wire chief's, monitor's and trouble clerk's desks and similar apparatus are duplicated at each exchange, will probably throw the balance in favor of the single large exchange. This matter, however, would need to be determined for each set of conditions, as it can not be said in all cases the office equipment for a single exchange would be cheaper than that of a greater number of exchanges furnishing service to the same number of subscribers.

All the factors so far considered, that is, the quality of service, the cost of operation, fixed charges and rent, and depreciation on the office equipment, seem to lean in favor of the single office, some of them decidedly so, others not so strongly. Against these must be put, in some cases, the interest and depreciation on the wire plant and the item of annual cost of maintenance.

By wire plant is understood everything pertaining to the telephone plant, from the subscriber's premises to that point in the telephone office, or offices, where the lines enter the terminal heads. It therefore embraces the underground conduits and cables, the pole lines carrying cables or bare lines, together with all necessary apparatus such as manholes, drop wires, etc.

It is easy to see that the average length of subscribers' lines will be greatest when a single office is used, and will steadily decrease as the number of offices is increased. It has been pointed out by Mr. F. J. Dommerque that in a given community the average length of subscribers' lines varies inversely as the square root of the number of offices. In other words, if the average length of subscribers' lines with one office is L, then the average length of subscribers' lines with N offices is approximately $L' = \frac{L}{\sqrt{N}}$ This law is not strictly true, but gives a close approximation. Mr. Dommerque, in planning the re-equipment of the system of the Chicago Telephone Company on an ultimate basis of fifty thousand (50,000) subscribers, found that the average length of line for the city of Chicago, if equipped with one exchange, would be twenty thousand (20,000) feet. From this figure and from the law of variation just stated, the curve shown in Fig. 1 has been plotted, giving the average length of subscribers' line for any greater number of offices up to sixty. It was found that the actual measurements of subscribers' lines for the various proposed layouts for the city of Chicago closely coincided with the figures of this curve, so closely in fact that such a curve was found to be a practically reliable source of information for any number of offices. A similar curve might be plotted for trunk lines and order wires connecting such offices, which curve would, of course,

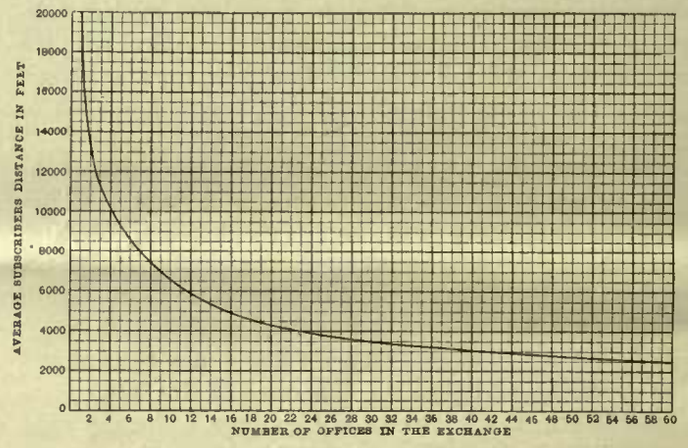

FIG. 1.—SUBSCRIBERS' LINE CURVE.

start with a zero ordinate for one office and rapidly rise with the number of offices.

It is interesting to conceive these curves, when carried to their limits; that is, when there were 50,000 central offices for 50,000 subscribers. The curve of subscribers' lines would then have a zero ordinate, while the curve for the trunk lines would have a maximum ordinate which would be equal in feet to the distance from one subscriber's station, through all of the other subscribers' stations. This means that there would be no subscribers' lines whatever, but that from each subscriber's station there would be a trunk line corresponding to every one of the 49,999 other stations, as these trunk lines would extend through all stations. We have an actual example of such a system as this in the ordinary house telephone system, where every subscriber has his own central office and where every subscriber's line extends to every other subscriber.

If there is but one exchange in the city, the proper location for it may be found by marking upon the map all of the subscribers present and prospective and then determining the center of gravity of the system, so to speak. This may readily be done by drawing a straight line through the map in such a manner as to have one-half of all the subscribers on one side of it and the other half on the other.

In a similar manner another line may be drawn at right angles to the first, bisecting the total number of subscribers, and the intersection of these two lines will probably be fairly close to the proper place for the central office.

A remote group of subscribers, not cut by these two lines, would tend to draw the true center of distribution from the point so located toward it. In order to avoid errors from this source, a number of other pairs of bisecting lines should be drawn, the lines of each pair being at right angles. Three such pairs of co-ordinates, 30 degs. apart, would locate three centers, probably close together, and the center of the triangles formed by these centers is a very close approximation to the center of distribution of all the subscribers.

With this location determined, it is an easy matter to determine the total average distance of the subscribers from it, and therefore the total wire-mileage of the subscribers' lines. With the average subscribers' distances as the base, a curve such as just shown, may be plotted, which will show in a close enough degree of approximation what the average length of subscribers' line would be for any other number of central offices.

Of course, as the number of offices increases, the wire-mileage of the trunk lines and order wires increases and figures concerning this must be worked out in consideration of the locations of the various offices and the amount of traffic between them. This latter factor, the traffic between offices, varies greatly according to the kind of districts connected, and it is therefore almost impossible to give general figures as to the mileage of trunk lines and order wires. It may be said, however, that the statistics of the large cities of this country and Europe show that the trunk and order circuit wire-mileage is approximately one-fifth of that of the subscribers' wire-mileage. It is evident that this figure can be used as a basis for laying out new exchanges, for, by the very nature of things, there can be no definite ratio between the two.

If it is found necessary for any reason to divide the system up into office districts, a great amount of care must be taken as to the proper boundaries for these districts. Of course, rivers, water fronts and railroads will frequently aid in the determination of these boundaries. There is frequently a tendency toward the use of large business streets and thoroughfares as boundary lines between districts, but investigation will show that in many cases this is not good practice, as such streets or thoroughfares should be the centers of distribution rather than the boundaries of them. Diagonal thoroughfares between offices should be used as trunk line routes, rather than boundaries of districts, owing to their directness and to the fact that a large number of subscribers are usually located in their vicinities.

Having decided on the boundaries of the districts, their respective centers may be determined, and between these the most available routes for trunk lines determined.

In figuring the cost of the wire plant for various layouts of a city, it will not do to assume the cost to be in direct proportion to the wire-mileage required by the systems using one office, or a greater number, for there is a factor entering the problem which greatly favors the single office or, I might say, greatly favors the fewer number of offices. This factor is due to the fact that with the single office system, or with the system using few offices, a greater amount, in proportion, if large conduit or cable may be used, and therefore the cost per conduit foot and per mile will be considerably smaller than where a greater number of offices are used.

In general, it may be said that the interest and depreciation on the wire plant decreases as the number of offices increases, and this is the main, and, in fact, practically the only item to offset the advantages of the fewer number of offices or the single office.

The interest and depreciation on the subscribers' apparatus would be the same, whether one or many offices were used.

A limitation to the size of switchboards has heretofore necessitated a greater sub-division of offices in very large cities, than any of the considerations so far pointed out would warrant.

Until recently, it has been the policy of the Bell Telephone Company to establish no central offices having switchboard capacity for over 6000 lines. This limit was maintained because of the fact that it has not been practicable to build multiple switchboards having a larger capacity than that. This limit in the capacity of the board has been due entirely to mechanical, rather than electrical conditions, and on account of it, it has been impracticable to build such exchanges as those of New York and Chicago with a single office, if other conditions had warranted it.

There has recently developed, however, a strong tendency on the part of the Bell and the Independent companies to build central offices with a much larger equipment than 6000. The Cuyahoga Telephone Company, of Cleveland, is now equipped with a multiple board having a capacity of nine thousand six hundred (9600) lines installed, and with an ultimate capacity of about twenty thousand (20,000). The board at Paris, France, equipped by the Western Electric Company, has a present capacity of something like nine thousand three hundred (9300) lines, and the Kinloch Telephone Company, of St. Louis, Mo., has a present equipment of eight thousand eight hundred (8800) lines. I am informed that a number of exchanges operated by the Bell Company are now being planned or built, having a capacity of nine thousand (9000) lines and upward.

I believe fully that the future systems in large cities will be operated with fewer and fewer central offices and consequently with larger switchboards. This belief is rendered tenable by the present tendency of operating companies and also recent improvements in switchboards by which the mechanical limitation of six thousand (6000) lines is removed and by which as many as twenty-five thousand (25,000) lines can be handled in a single straight multiple switchboard and even as great a number as one hundred thousand (100,000) lines by the use of systems now shown to be practicable for a smaller number.

The fundamental object of the multiple switchboard is to place within reach of every operator a line terminal or spring jack, as it is called, for every subscriber's line entering the exchange. As is well known, the switchboard is divided into sections, each section being of such size as to allow an operator, without undue exertion, to reach over its entire surface. On each section are placed a certain number of line signals, by which the subscriber is enabled to attract the attention of the operator and a corresponding number of line jacks, by means of which the operator may make the initial connection with that line in response to such signals. These jacks, which are associated with the line signals, are termed answering jacks. In addition to the

line signals and answering jacks are provided what are termed multiple jacks, there being one of these on each section for every line in the exchange. To express this in a little different way; the various lines entering the central office are divided up into suitable groups, these groups terminating in line signals and answering jacks at the various sections of the multiple switchboard. In addition to this, all the lines entering an exchange are carried to every section of an exchange, each line terminating in every section in a multiple jack. An operator seated at any section, in response to a display of one of her line signals, inserts one plug of a pair into the corresponding jack, and, having ascertained the number of the subscriber desired, inserts a corresponding plug of the pair into the multiple jack of the subscriber called for. As every subscriber's line has a multiple jack at every section of the switchboard, any operator is able to complete by herself any connection called for at her board.

The size of the section is limited by the reach of the operator, and it is this fact that places a mechanical limit to the size of an ordinary multiple switchboard. It has been found impracticable in most cases to place the jacks closer than on half-inch centers, and under these conditions no more than six thousand (6000) of the multiple jacks could be placed, in addition to the other apparatus, within the space afforded by one section.

Two distinct methods have been followed with the intent of removing this limit. Each has been productive of excellent results; each has been used separately, but up to the present time they have not both been incorporated into the same installation. The first of these methods is an obvious one and contemplates the reduction in the size of the spring jacks with a view to getting more of them within the reach of the operator. The mechanical difficulties in this line have been great, owing to the fact that the circuits of the switchboard were so complicated as to require three, four, and sometimes even five contacts to each spring jack. The Western Electric Company in the Paris board succeeded in reducing the dimensions of the jack to three-eighths of an inch ($\frac{3}{8}$-in.) centers, both horizontally and vertically, and thus rendered practicable the installation of a switchboard having a capacity for considerably over nine thousand (9000) lines. I believe that there are other boards which have been installed with success having this size of jack, and that others are at present in course of construction for large cities in this country. This jack had three contacts, and I believe is the smallest that has ever been put into extensive use.

Quite recently the company with which I am connected has perfected a system of circuits for a multiple switchboard so simplified that only two contact points are required for each jack; that is, merely a tip spring and sleeve, these two contacts always standing open and never engaging each other. By the use of this two-wire system, it is perfectly practicable to build the jacks on $\frac{1}{4}$-in. centers, horizontally and vertically, and thus place within the reach of a single operator no fewer than 25,000 lines.

The second method of increasing the possible size of multiple switchboards was devised by Mr. M. G. Kellogg, and is now working in two large exchanges in this country. In this system, which is known as the divided multiple system, the switchboard and lines are divided each into four divisions. The switchboard consists of four multiple boards, all in the same office, and to these is connected one of the groups of lines, in the same manner as if they were in separate exchanges. With this arrangement, if no further provisions were made, it would be possible for any subscriber in one division to obtain a connection with any other subscriber in his own division, but not with any one in any of the other three divisions. In order to enable any subscriber in, say, the A division to obtain a connection with a subscriber in the B, C or D division, means are provided, not for trunking between the divisions, but for enabling the calling subscriber to signal directly to one of the operators in the division in which the line of the called-for subscriber belongs. This necessitates the use of four line signals and four answering jacks for each line, one of each in each division, and of means whereby the subscriber may display any one of the signals to the exclusion of the others. Instead of trunking between exchanges, therefore, the subscriber sends his call directly into the division of switchboards to which the desired subscriber belongs.

By the use of this divided multiple switchboard it is seen that the ultimate capacity of any exchange is increased approximately fourfold; not quite this, however, because the extra line signals and answering jacks take up a portion of the room which would otherwise be available for the multiple jacks.

The significance of what I have said concerning the two methods of increasing the size of multiple switchboard will now be apparent. If the four division exchange were installed on $\frac{1}{4}$-in. centers, the capacity of such an exchange would be something over 90,000 lines operating without giving the operator as great a reach as they have at present in some multiple switchboards, and between the subscribers of this mammoth exchange there would be no trunking whatever.

You may say that the divided multiple system introduces complications in the circuits, which is true! You may also say that operators will find difficulty in handling the jacks on $\frac{1}{4}$-in. centers, which may or may not be true! But with the demand for telephone service growing with an ever increasing rate as at present, who will say that the 100,000-line switchboard will not be required in the near future, and who at present can conceive of any other way of handling it?

During the past five years a complete revolution has been worked in the circuits and apparatus of telephone exchanges, due to the introduction of the systems known under such names as "common battery," "central battery" and "central energy." These systems, when properly equipped, have proven vastly superior from both an economic and operating standpoint to the old magneto systems, wherein local batteries were used for talking and magneto generators for making the calls. The local primary battery at the subscribers' station has been superseded by a large storage battery at the central office, which also takes the place of the old magneto generator. The mechanical signal or drop has given place to the lamp signal. By these innovations the apparatus at the subscribers' station has been rendered simpler and more compact, that at the central office more reliable, and the operation of the entire system has been rendered automatic as far as the subscriber is concerned, and as much so as desirable as far as the operator is concerned. Such a system employs batteries at the central office for furnishing all current, for signaling by the subscriber and for the operation of the talking apparatus. These batteries are invariably secondary, rather

than primary, for large exchanges, and operate almost universally at the voltage given by ten cells in series, *i. e.*, 20 to 24 volts, according to state of charge.

For charging these batteries and for furnishing current for ringing the subscribers' bells complete power plants are required, these consisting of suitable generating units, driven either electrically or mechanically, together with suitable controlling apparatus. Most companies depend

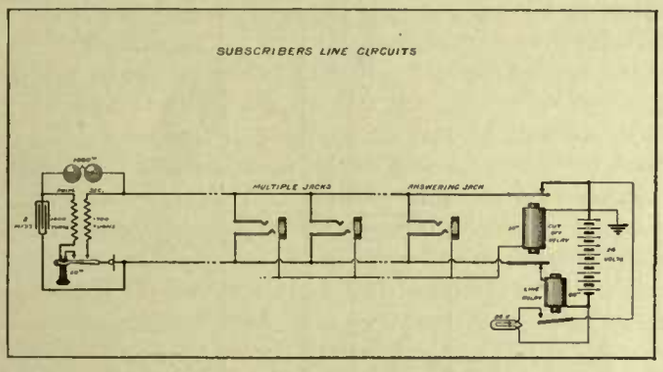

FIG. 2.—CIRCUIT.

upon electrical power, the charging and ringing machines being motor generators running directly from city mains.

It may be imagined that the failure of any source of energy in a large telephone system is a matter of most serious moment. The cutting off of one branch of the current supply would cause consternation in the entire business organization of a community. In order to prevent any such breakdown, all portions of the power plant are made in duplicate, and where it is possible duplicate primary sources of power are also made available. Frequently the large telephone companies employ their own steam generating plant, which they use constantly, with the current from city mains as a reserve supply.

The determination of the size of the storage batteries is the primary problem in the engineering work in connection with the telephone power plant, as, having once determined it, the size of the charging machines and the details of the other apparatus are readily ascertained. We know in a given city approximately the number of subscribers to be provided for in the present installation, and we make a guess at what the future number will be. Past experiences have proven that these guesses are almost always too small, for the growth of telephone service in the United States has far exceeded expectations. We also know by statistics from other cities approximately the number of calls each subscriber will make per day. This figure ranges from about eight calls per day in smaller and less active cities to something like thirty calls per day in our largest business centers. Experience has also taught us that the average length of time from the time a subscriber takes his telephone off his hook in making the call to the time the connection is completed with the subscriber called for will vary not far from six seconds, if the service is prompt; and that the average length of conversation is somewhat less than two minutes. Knowing these figures and the average length, and therefore the average resistance of the various subscribers' lines, and of the connecting apparatus, the number of ampere-hours required for the subscribers' circuits is readily determined. To this must be added the number of ampere-hours required for the operators' transmitter circuits, the supervisory lamp circuits, and any other circuits that may exist. The whole may be reduced to a certain number of hundredths of ampere-hours per connection, a most convenient unit.

Knowing the total number of ampere-hours required of the storage battery in a day, a size of battery should be selected having that capacity in ampere-hours, and also one having a discharge rate in amperes equal to one-sixth of the total ampere-hours required. Experience has shown that the maximum discharge rate is equal to about one-sixth of the ampere-hours required per day.

The circuits of a telephone exchange are of such a complex nature as to defy adequate explanation in the short time available.

In the modern common battery exchange the operation is such that when a subscriber removes his receiver from the hook, a lamp will be automatically lighted in front of the operator at the central office, who handles the calls of the group of subscribers to which this particular subscriber belongs. The operator in response to this signal makes connection with the subscriber's line by inserting a plug into the spring jack of that line, and after having ascertained his wants, completes the connection with the subscriber called for by means of a second plug attached to the first. As soon as a connection is thus made with a subscriber's line, the line lamp normally in control of the subscriber is disassociated from the line, but another lamp associated with the plug is placed under the control of the subscriber, this lamp being known as a supervisory lamp.

In Fig. 2 is shown a complete line circuit in diagram, including the apparatus at the subscriber's station, which is shown at the left, and the apparatus at the central office, which is shown at the right. The apparatus at the sub-

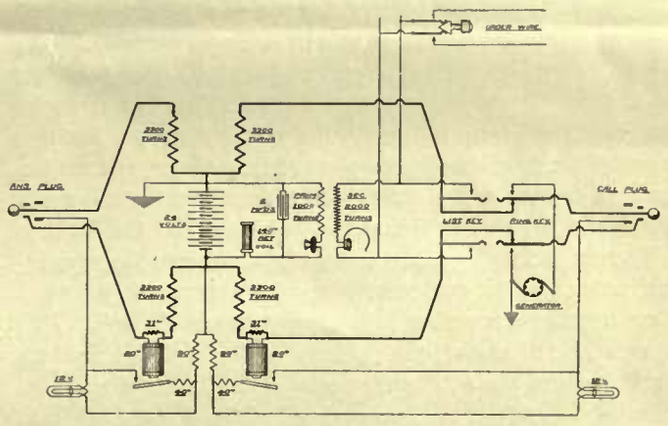

FIG. 3.—CIRCUIT.

scriber's station consists of an induction coil, a receiver, a granular carbon transmitter, a two micro-farad condenser, a 1000-ohm bell and an automatic hook-switch mounted in a suitable manner. It will be noticed from the diagram that the circuit between the two sides of the line is held open to direct currents by the condenser, and to all currents by the hook-switch contact, while the receiver is on the hook. This leaves the bell in operative relation to the line, for the purpose of receiving calls; the path of the ringing current, which current is, of course, alternating, being through one side of the line, through the bell and condenser to the other side of the line. When the receiver is removed from its hook, the circuit between the two sides of the line is closed, allowing the passage of direct current through the secondary of the induction coil and the transmitter in series. At the same time another circuit containing the transmitter, the receiver, the primary of the induction coil and the condenser is closed. The ob-

ject of this latter circuit, which is local to the subscriber's station, will be pointed out later.

At the central office, in addition to the answering jack and the multiple jacks, there are two relays, one termed the line relay, which is normally in circuit across the line in series with the 24-volt storage battery common to all

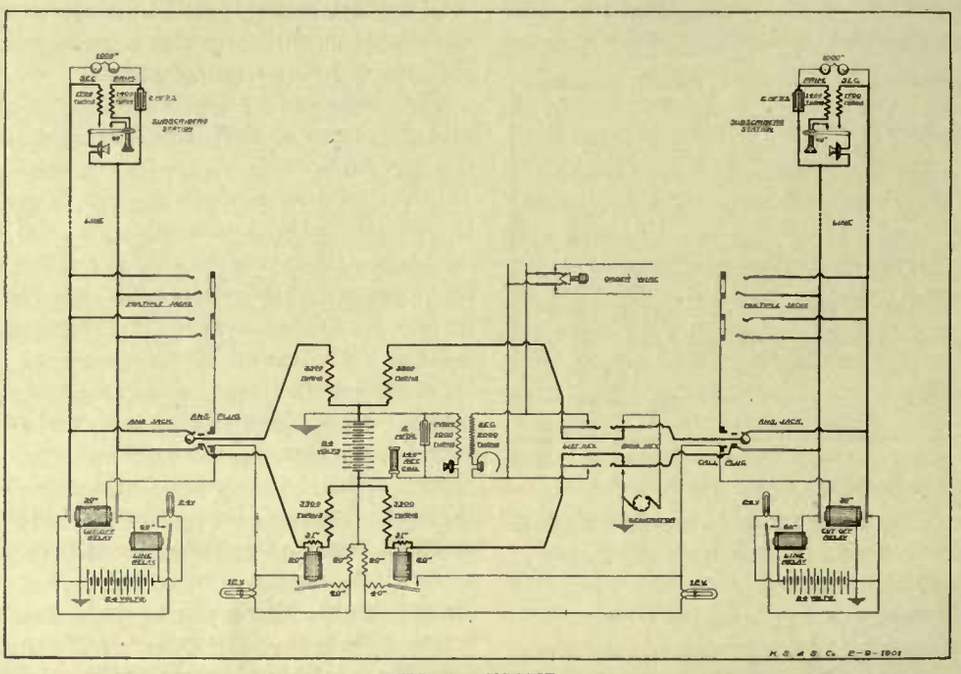

FIG. 4.—CIRCUIT.

lines, and the other termed the cut-off relay, which is in an auxiliary circuit, and is adapted to open the circuit through the line relay and the battery as soon as a plug is inserted into any jack belonging to its line. Under normal conditions, both relays remain unoperated and the conditions are as shown. As soon, however, as the subscriber removes his receiver from its hook, the circuit between the two sides of the line is made complete at the subscriber's station and the current at the central office energizes the relay and closes the circuit containing the line lamp and the battery. This lamp is located in immediate proximity to the answering jack, and the operator, seeing it illuminated, inserts a plug into the answering jack in response to the call. This plug is one of many pairs within the reach of the operator and has three contacts, two of which, the tip and sleeve, are adapted to engage the two springs of the answering jack, and thus complete the talking circuit. The third is adapted to engage the ring contact of the jack, and being in connection with the live side of the battery, causes a current to pass from this side of the battery through the ring contact of the jack and the coil of the cut-off relay back to the other side of the battery. The energization of the cut-off relay serves to open the circuit of the line relay, as already described, and this, when operated, extinguishes the lamp.

One of the cord circuits is now shown in Fig. 3. In this the answering and calling plugs are shown at the extreme left and right-hand portions, respectively, each having, as beforesaid, three contacts, two of which, the tip and sleeve, are connected by wires shown in heavy lines, which form part of the talking circuit, and the third of which is connected through the supervisory signaling apparatus to the live side of the battery, as shown. The tip and sleeve sides of the answering plug are connected together through the two halves of one side of a repeating coil, between which is connected the common battery. In the same manner the tip and sleeve strands of the calling plug are connected by the two halves of the other winding of the repeating coil between which is connected to the same battery.

This repeating coil, and there is one of them for each pair of cords and plugs, has four windings, each having approximately 3300 turns, all of these windings being on the same magnetic core. It is evident that these connections allow direct current from the storage battery to pass out over the metallic circuits of the two connected lines to energize the transmitters. A fluctuation in the current flowing in either line will, however, by induction between the windings of the repeating coil, cause a corresponding fluctuation in the current of the other line. In this way conversation between two connected lines is made possible, it being by induction rather than conduction.

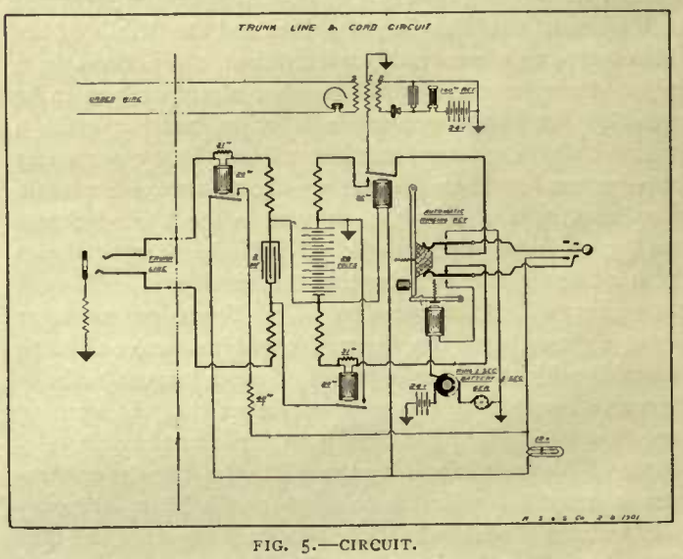

FIG. 5.—CIRCUIT.

In the sleeve strand of the cord of each plug is connected a supervisory relay, which is energized, as is readily seen, only while current is flowing over the line to which the corresponding plug is connected, *i. e.*, while the receiver of that line is off its hook. These relays control the circuit of supervisory lamps, by the illumination or darkness of which the operator is enabled to ascertain the condition of the connected lines. On the right of this figure is shown

the ringing and listening keys. The former is a device for switching the alternating current generator into the circuit of the calling plug and its connected line; the latter connects the operator's head telephone, which is shown in the center of the diagram, across the two sides of the cord, in order to enable the operator to communicate with either subscriber.

The operation of this circuit and apparatus can best be understood by referring to Fig. 4, which shows two subscribers' lines equipped as already described, connected by a cord circuit at the central office. Consider the line at the left to be that of the calling subscriber and that at the right the called. In the first place, the removing of the calling subscriber's receiver from its hook illuminates the line lamp, which remains lighted until the operator answers by the insertion of the answering plug into the answering jack. The operator, before inserting the calling plug into the jack of the called subscriber, must ascertain whether or not the line of that subscriber is already busy. This is automatically accomplished, for upon the touching of the tip of the calling plug to the ring contact of the multiple jack, she will get a click in her head telephone if the line is busy, and silence if it is free. If the line is free, she inserts the plug to its full extent, and presses her ringing key, which rings the subscriber's bell. As soon as the calling plug is inserted the supervisory lamp, shown at the right-hand lower portion of the figure, will be illuminated, because its circuit will be completed from ground through the battery, through the 90-ohm resistance coil and the lamp; thence through the third strand of the cord, the test ring contact of the jack, and to ground through the cut-off relay. This current will not only illuminate the lamp, but will operate the cut-off relay of the line called for as well. As soon as the subscriber of this line responds, he will close the circuit between the two sides of his line and thus allow current to pass over the line to operate the transmitter. This current will pass through the supervisory relay, which will then be operated to close the low-resistance shunt about the lamp and thus extinguish it. Both lamps are now out, and the operator pays no further attention to the connection until she sees one or both of the supervisory lamps again lighted. The corresponding lamp will be lighted when one or both of the subscribers hang up their receivers, which act will, by opening the circuit of the line, cause the corresponding supervisory relay to let go of its armature and thus remove the shunt about its lamp. When both lamps are thus lighted, the operator knows that the connection is no longer desired, and without further inquiry pulls down the plugs.

It is evident that any fluctuation in the resistance of the current of a transmitter at one subscriber's station will cause a corresponding fluctuation of the current flowing in the line, and this fluctuation will pass through the two windings forming one side of the repeating coil, which will act inductively on the two windings forming the other side of the repeating coil and produce a corresponding fluctuation in the other line. This latter fluctuation will pass through the secondary winding of the induction coil and the transmitter at the subscriber's station, and induce a corresponding fluctuation in the local circuit containing the receiver and the condenser.

One of the functions of this local circuit, which has already been referred to, is that of putting the receiver in inductive relation to the line without subjecting it to the passage of direct current through it, which circumstance might tend, if the receiver were connected up the wrong way, to demagnetize its magnets. This local circuit is, however, designed to accomplish still another result, this being the formation of a comparatively short path, through which the fluctuations set up by the transmitter may more readily pass; in other words, it is supposed to act as the local circuit of a sort of a booster to the outgoing telephone currents. The fluctuation in current caused by the transmitter pass through the condenser and primary winding of the induction coil, and thus induce on the secondary, which is in the line, fluctuations which tend to increase the fluctuations directly produced in the line by the transmitter.

So far, only such means have been described as would admit of the connecting of two subscribers whose lines terminate in the same exchange. Where several offices are used in the same system, the connections between subscribers in different offices are, as has already been pointed out, made by trunk lines extending between the offices. These trunk lines are spoken of as outgoing or incoming,

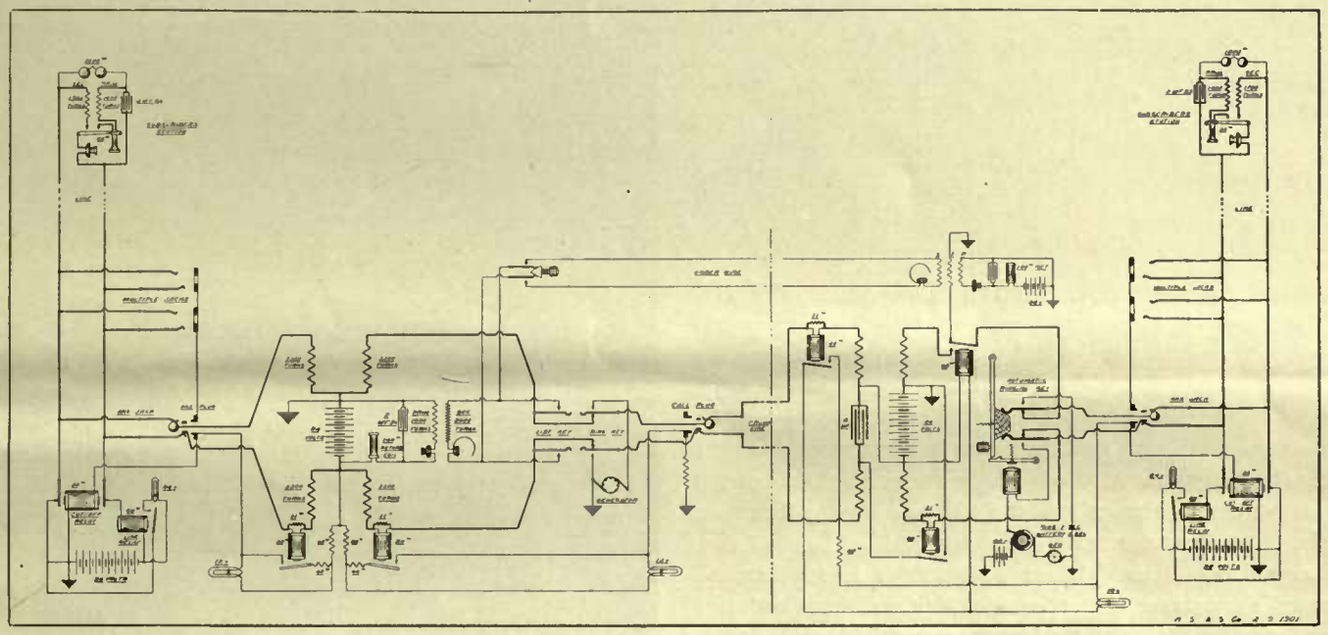

FIG. 6.

FIG. 7.

according to which end of them is referred to. Thus an outgoing trunk line at one office would be an incoming trunk line at another. The distinction is obvious. The outgoing trunk lines usually terminate in jacks, in the regular sections of the multiple switchboard, while the incoming trunk lines usually terminate in plugs and cords and special apparatus, arranged at special incoming trunk sections, which sections are provided with multiple jacks in the same manner as the regular sections.

In Fig. 5 I have shown the circuits of a trunk line. The outgoing end of it at one office being shown at the left of the dotted line, while the incoming end, with its

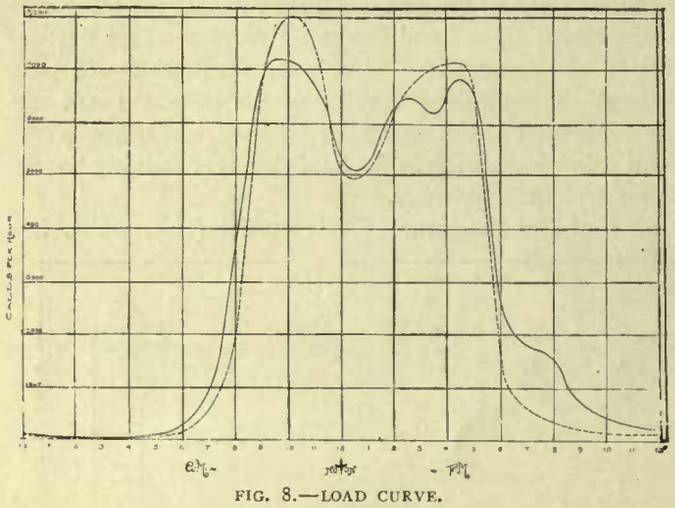

FIG. 8.—LOAD CURVE.

accompanying apparatus, is shown at the right. This circuit is somewhat complicated and will be better understood in connection with Figs. 6 and 7, which shows a subscriber in one exchange connected through the local cord circuit at that exchange, and a trunk line with a subscriber at another exchange. Assuming that the subscriber at the left has sent in a call, the operator at one of the regular sections of the switchboard will answer it in the ordinary way by inserting a plug into the answering jack, and having learned that the connection desired is for a subscriber in another exchange, she presses her order wire key and communicates over the order wire with the incoming trunk operator at one

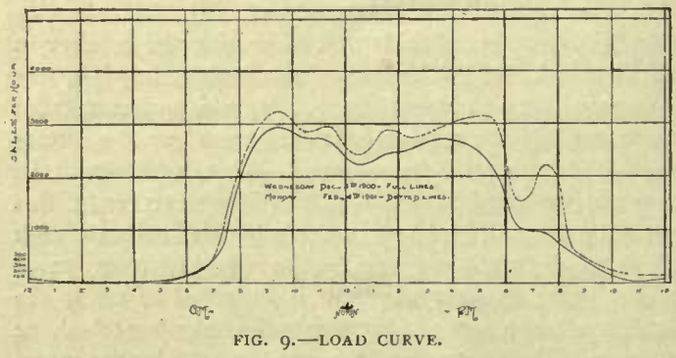

FIG. 9.—LOAD CURVE.

of the incoming trunk sections of the branch exchange. The incoming trunk operator repeats the order and gives the number of an unused trunk line to the operator at the first exchange. The incoming trunk operator at the second exchange then tests the line in the ordinary way with the trunk line plug, and if it is found free, she completes the connection by inserting the plug in the multiple jack of that line. As soon as this operator completes the connection, she sets the automatic ringing key, shown just to the left of her plug, which locks in the ringing position, because its controlling relay is not operated. The ringing generator is provided with an interrupter, each revolution of which switches the ringing current on to the line for one second and the 24-volt battery on to the line for five seconds. Thus the subscriber's bell rings for one second of every six until he removes his receiver from its hook. When he does this, the current from the 24-volt battery or from the ringing generator, whichever happens to be in circuit, passes through the primary magnet of the ringing key, and trips the latter into its normal position. By this means the bell of the subscriber is rung at intervals until he responds without any further attention on the part of the operator.

The insertion of the trunk plug into the jack of the called subscriber's line allows current to flow from the battery through the test relay and disconnect lamp, shown at the extreme lower right-hand portion of the figure, and thence through the cut-off relay to ground. This does not light the disconnect lamp, because that lamp is already shunted by the armature of another relay contained directly in the trunk line circuit, this latter relay having been operated by the insertion of the plug into the trunk line jack at the

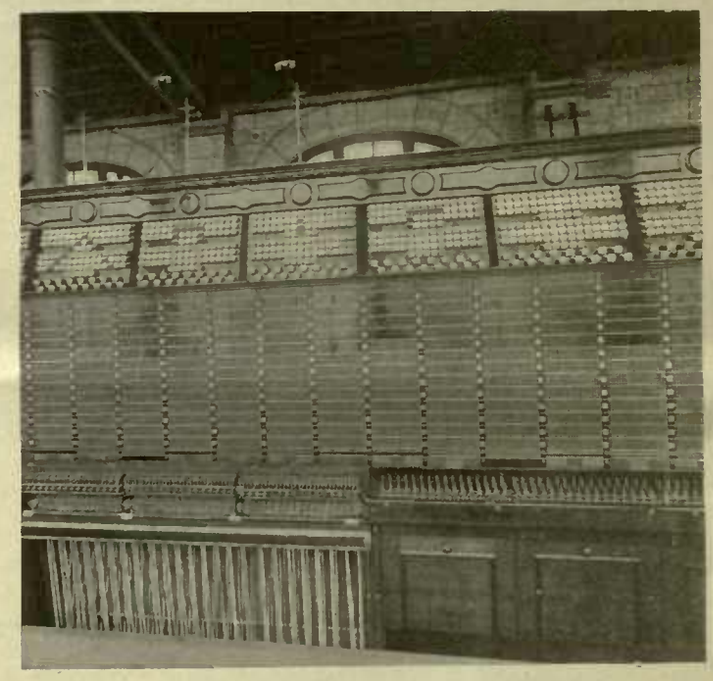

FIG. 12.—FRONT OF PARIS EXCHANGE.

other exchange. As soon as the ringing key is tripped, the current from the battery at the incoming end of the trunk line flows through the metallic circuit of the subscribers' line to furnish current for talking. This operates the supervisory relay in the incoming cord circuit, and puts a ground on the sleeve side of the cord circuit at the first office, thereby operating the calling supervisory relay at that office, and this shunts the corresponding supervisory lamp and extinguishes it, thus showing to the regular operater at the first office that the subscriber has responded. As soon as the subscriber called for hangs up his receiver, the supervisory relay at the incoming trunk section lets go of its armature and removes the ground from the sleeve side of the trunk line. This causes the calling supervisory relay at the first office to let go of its armature and remove the shunt from around the corresponding lamp. When both lamps of the regular pair of cords at the first office are lighted, the operator at that office pulls down the connection. By thus removing the calling plug from the trunk jack, current ceases to flow in the trunk line relay at the

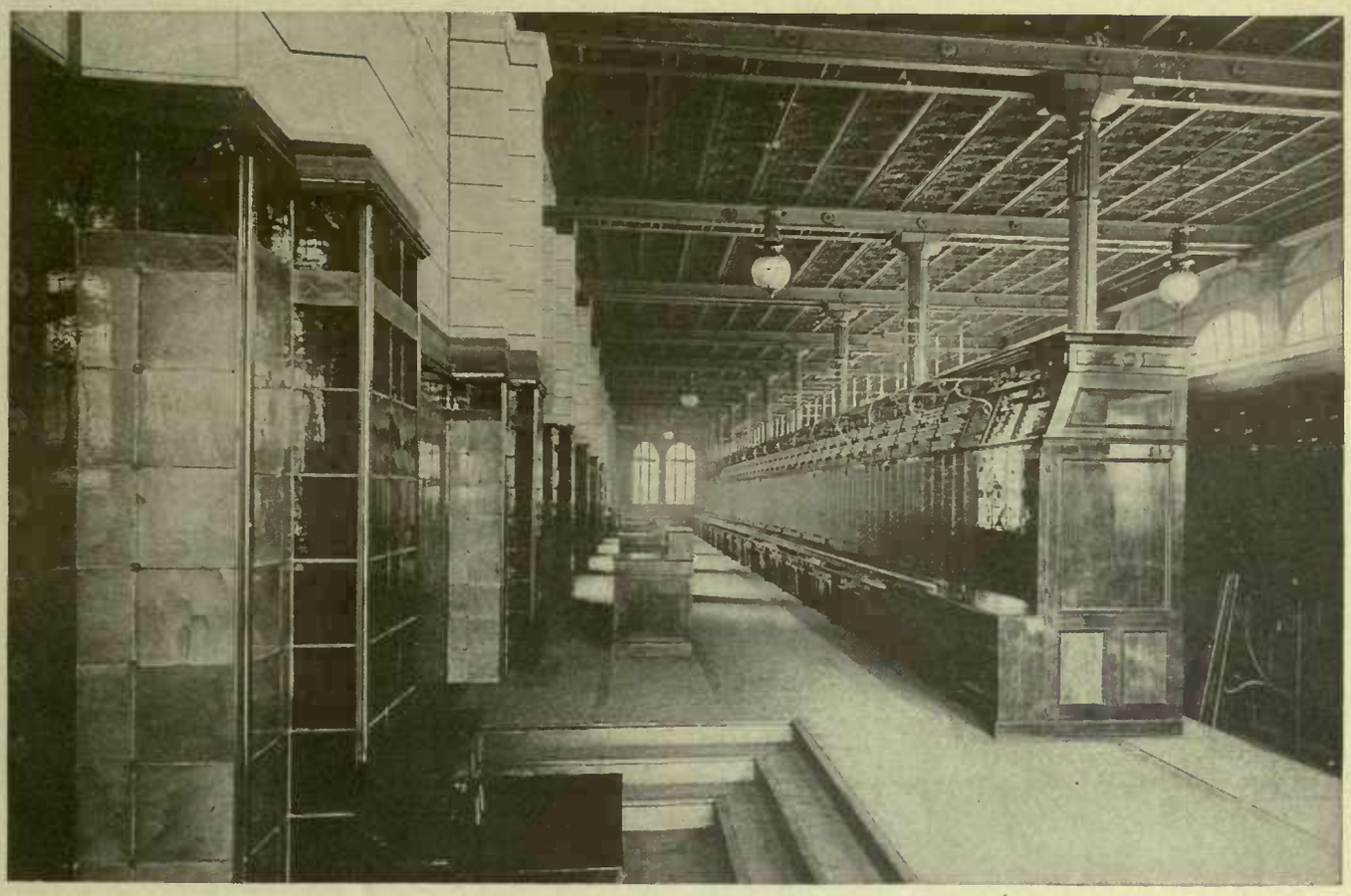

FIG. 10.—PARIS EXCHANGE.

second office, which removes the shunt from the disconnect lamp at that office and allows it to be lighted for the first time. This is a signal for the incoming trunk operator to disconnect.

It will be seen from the above circuits that when two subscribers are connected over a trunk line, they are under the control of the originating operator. The disconnect signals from both subscribers go direct to this operator, and it is not until she has pulled down this connection that the disconnect signal is given to the operator at the other exchange. The latter operator has no means of listening in on the circuit.

An interesting feature about such trunking systems is the means by which the incoming trunk operator at the second office informs the calling subscriber and the regular operator that line called for is busy. When she finds on testing that a line is busy, she inserts the trunk line plug into a "busy back" jack, which jack has connected in its circuit the machine giving an interrupted current which gives a peculiar, familiar, and, to most subscribers, an ex-

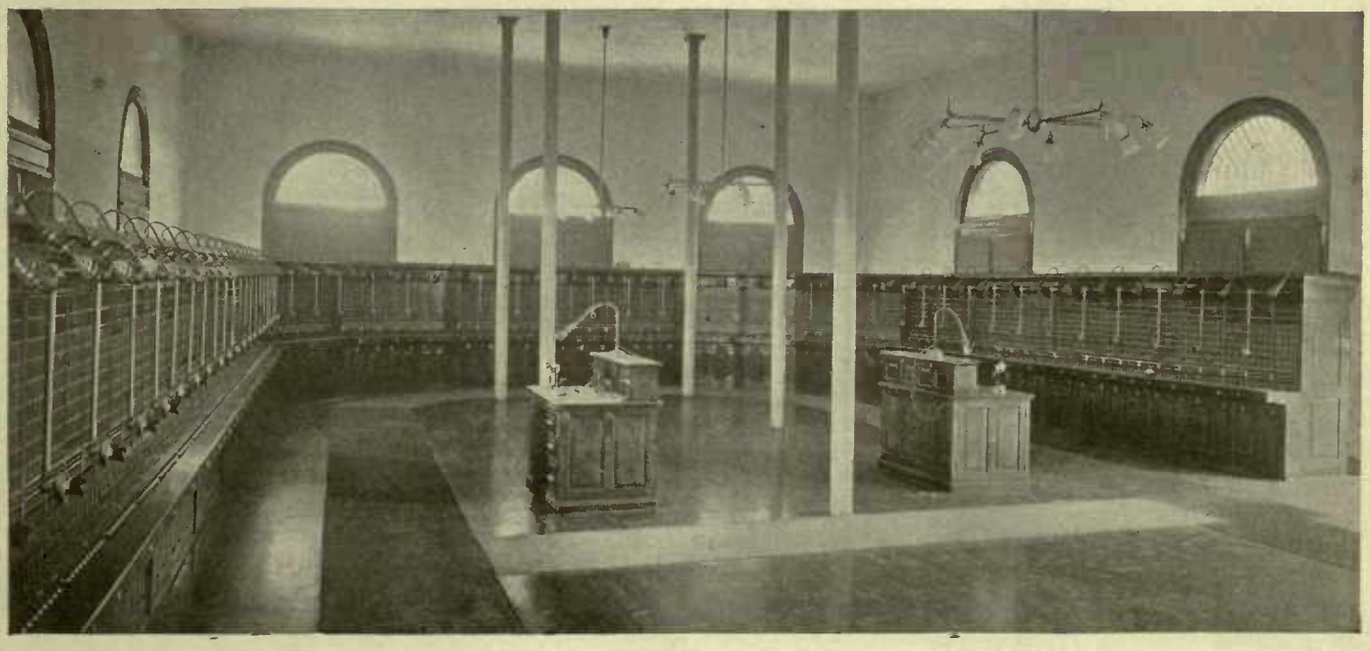

FIG. 11—PITTSBURG EXCHANGE.

tremely disagreeable sound. This sound is heard by both operator and subscriber at the first office, and the disconnection is made.

* * * *

There is probably no method of determining the relative activity of any city at different times of the day or on different days, so well as by watching the telephone exchange in that city in operation. For keeping track of their business and being able to handle it to the greatest advantage, telephone companies usually make at frequent intervals what they term "peg counts." These show the total number of calls received and connections made during each of the twenty-four hours of the day. These results, if plotted in the form of a curve, in which the abscissæ represent time and the ordinates represent total number of calls per hour,

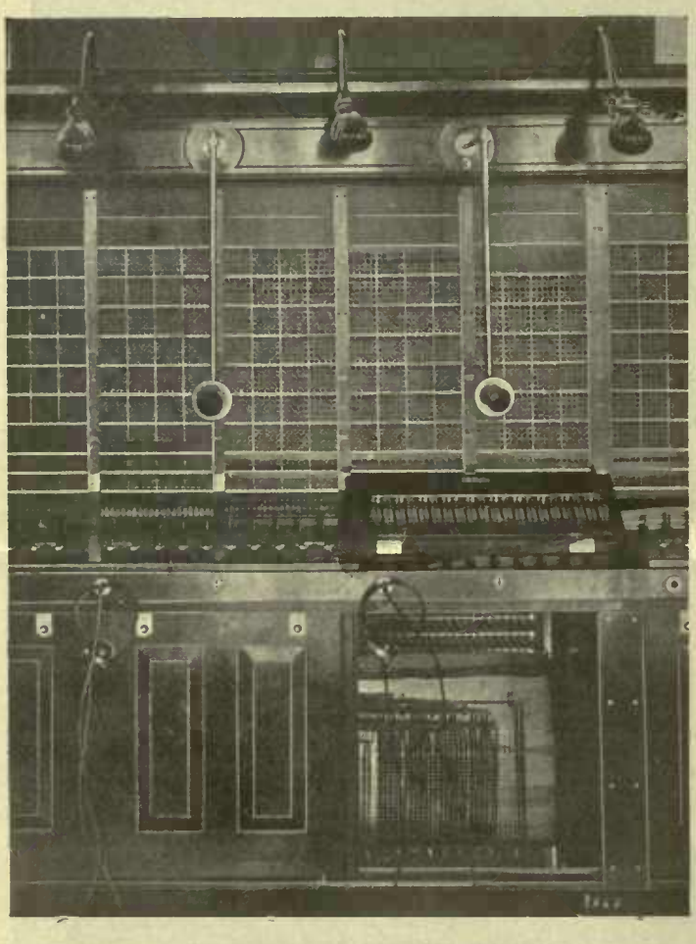

FIG. 13.—FRONT OF PITTSBURG SECTIONS.

show graphically and in a striking way the amount of telephone business being transacted at any given hour. The curves (Fig. 8), show what I believe has never been shown before—that is, peg counts, taken the same day, of two opposition exchanges in the same city. These exchanges have about the same number of subscribers, not far from 6000. The dotted curve represents the telephone activity in the Bell exchange, while the solid curve represents that of the Independent exchange. The rates of the Bell exchange are considerably higher than those of the Independent, and from this fact we are enabled to draw several conclusions from the form of the two curves.

It will be noticed that from twelve at midnight until six o'clock both curves are very low, and gradually fall until three o'clock, after which they slowly rise until six. This shows conclusively that the hour of 3 A. M. is that of least business activity, except, perhaps, in those lines, such as burglary and other allied industries which seldom require the use of telephone service. From the hour of 6 A. M. each of the curves rise rapidly, corresponding to the awakening of the city, reaching a maximum for the day in the neighborhood of ten o'clock, A. M. They then fall off

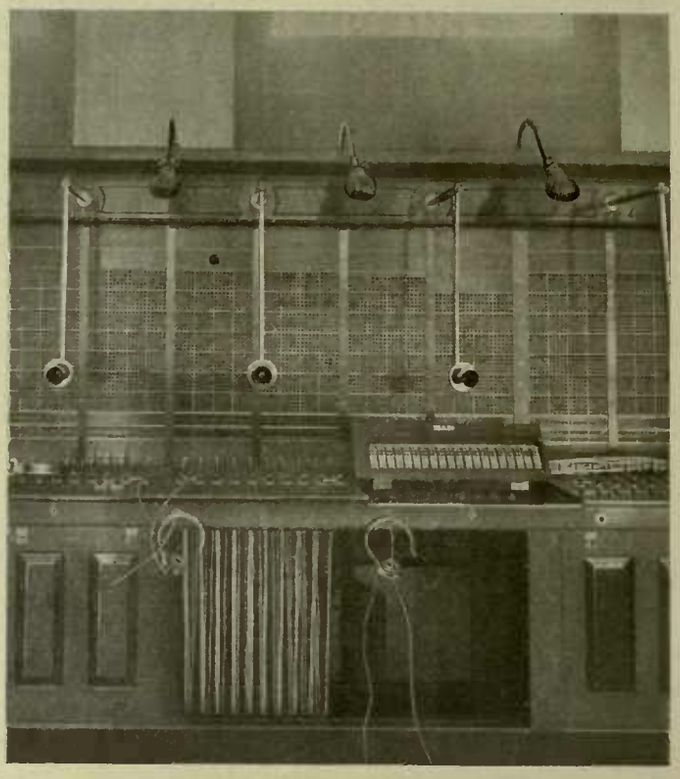

FIG. 14.—FRONT OF PITTSBURG SINGLE SECTION.

to a minimum, corresponding to the lunch hour, between twelve and one, and again rise to a second maximum between the hours of four and five in the afternoon, after which they rapidly fall during the evening hours. The fact that the Independent exchange has cheaper telephones

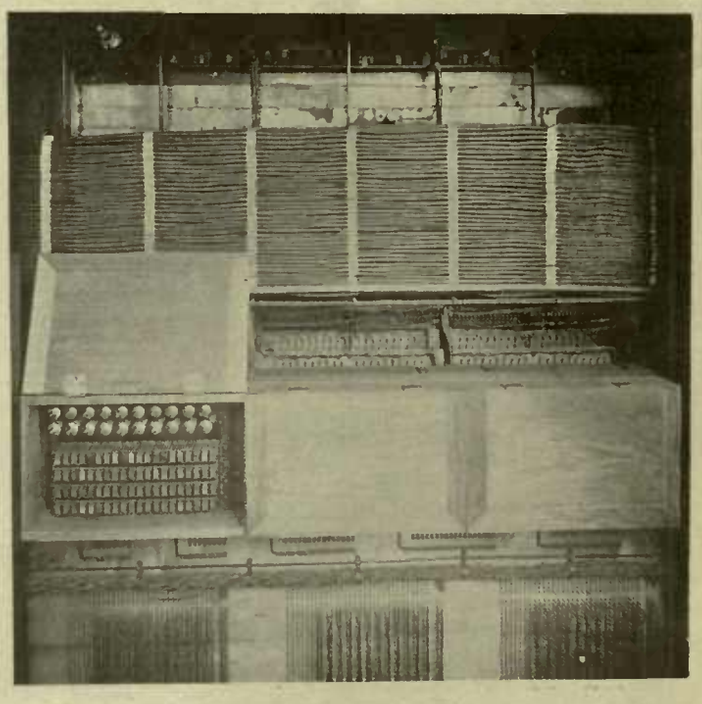

FIG. 17.—REAR OF PITTSBURG SINGLE SECTION.

than the other will, perhaps, account for the fact that its subscribers begin work a little earlier in the morning, reach their maximum activity at a little earlier hour, take a little shorter time for lunch, go home a little later in the evening

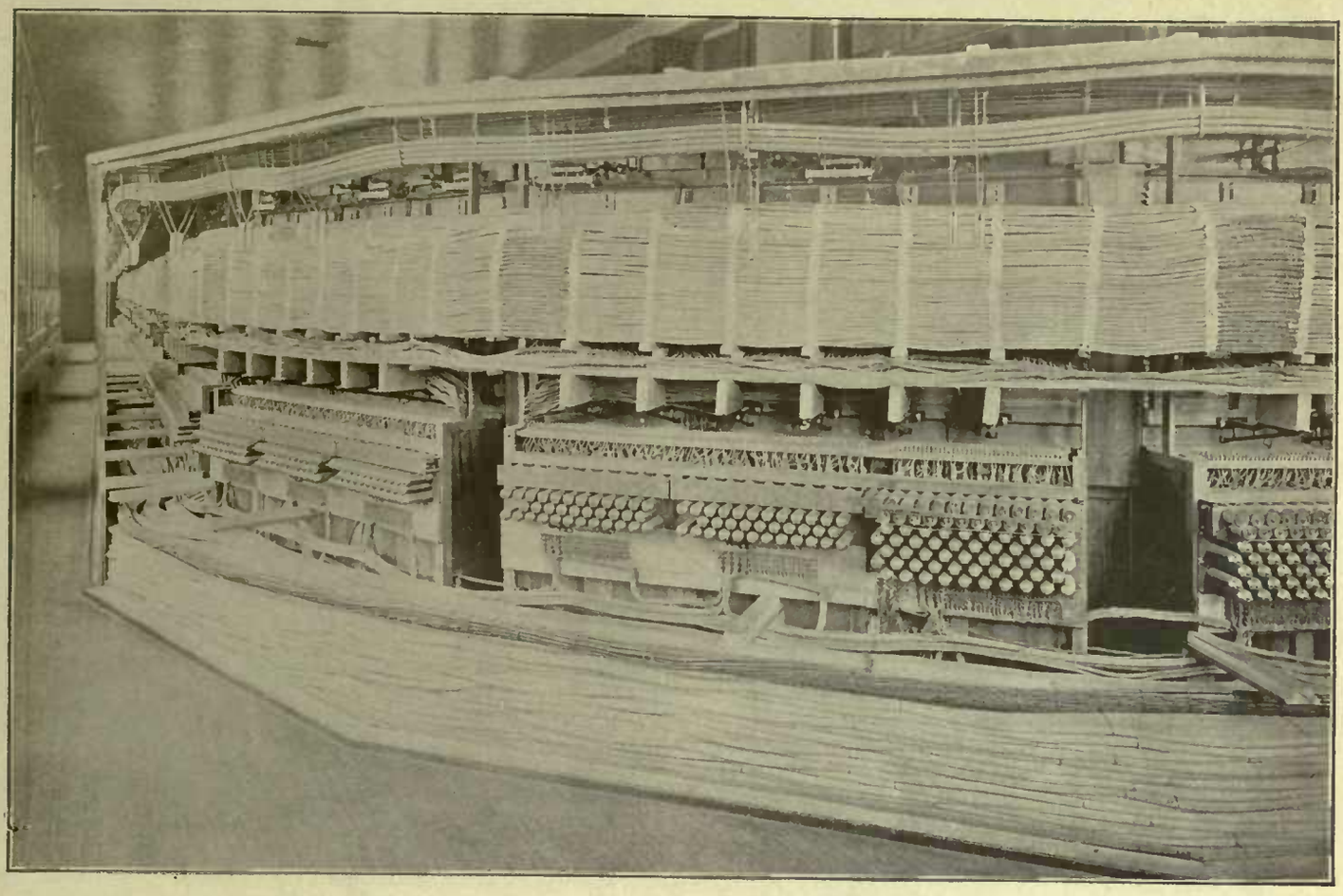

FIG. 15.—REAR OF ST. LOUIS SWITCHBOARD.

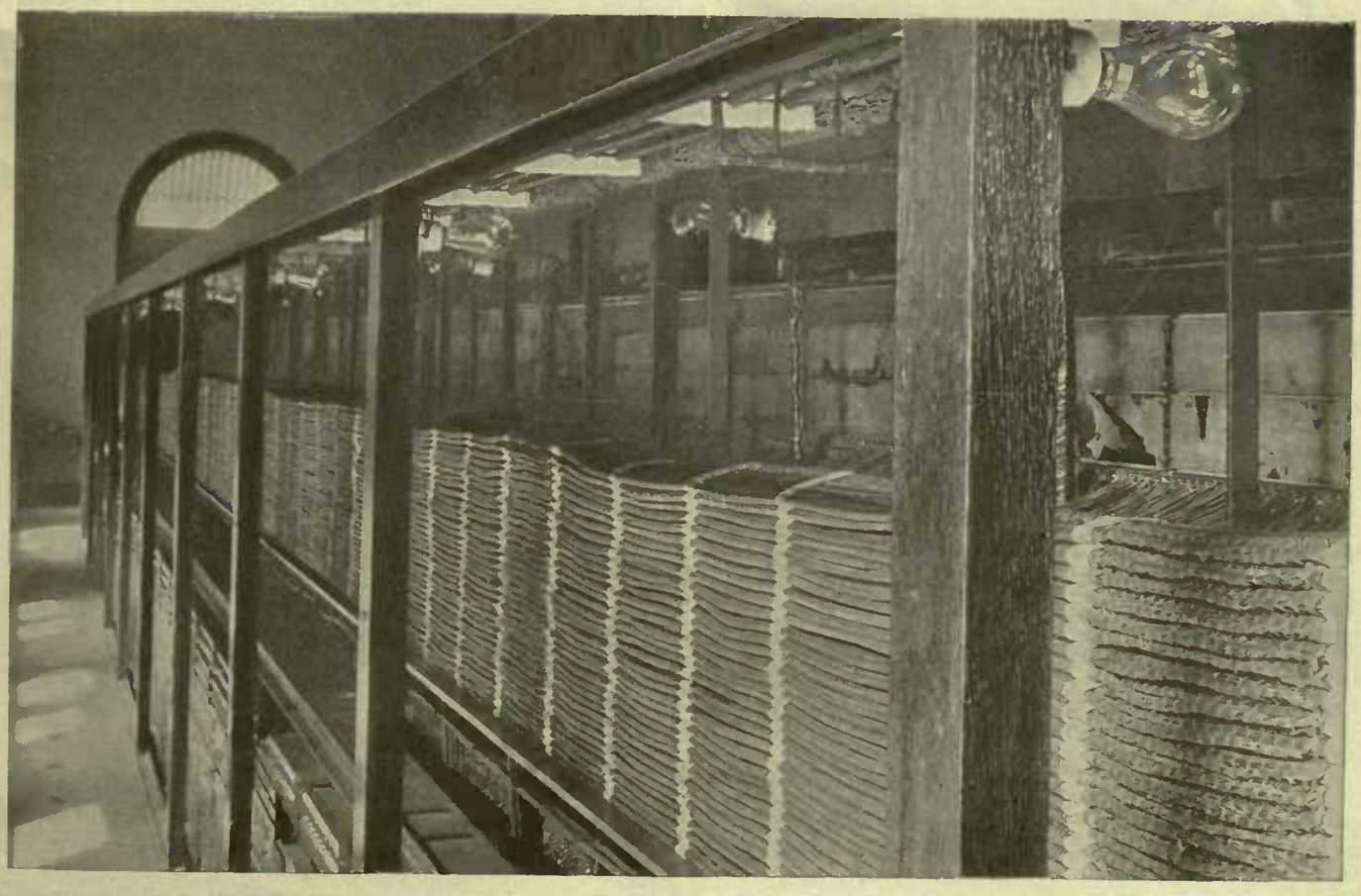

FIG. 16.—REAR OF PITTSBURG MULTIPLE.

and work a little more all night, all of which facts are indicated by these two curves.

In Fig. 9 I show two curves representing telephonic activity of the same city on two different dates. It will be noticed that the dotted curve, which represents a Monday, shows a greater number of calls than the solid curve, which was taken on a Wednesday. It is usually true that Monday is about the busiest day in the week in telephonic exchanges. It would be interesting to trace the significance of the different humps or characteristics of these curves, but it will be noticed that whatever hump is on one is present, or at least suggested, on the other. The pronounced hump on the dotted curve at the extreme right is undoubtedly due to the theater business, between seven and eight in the evening. Probably the reason why this was more pronounced on one curve than on the other was that there was a special attraction or special set of attractions, in the entertainment line, on the particular day on which the curve was taken. Such curves as these have been said by someone to represent the pulse of a city, and I think that the longer one thinks about it, the more apt this term appears. Every city has a heart in its telephone exchange, and this heart is throbbing with as great a regularity as that of any living creature.

I will now, in conclusion, show a number of pictures of telephone exchanges and apparatus, which I think will be

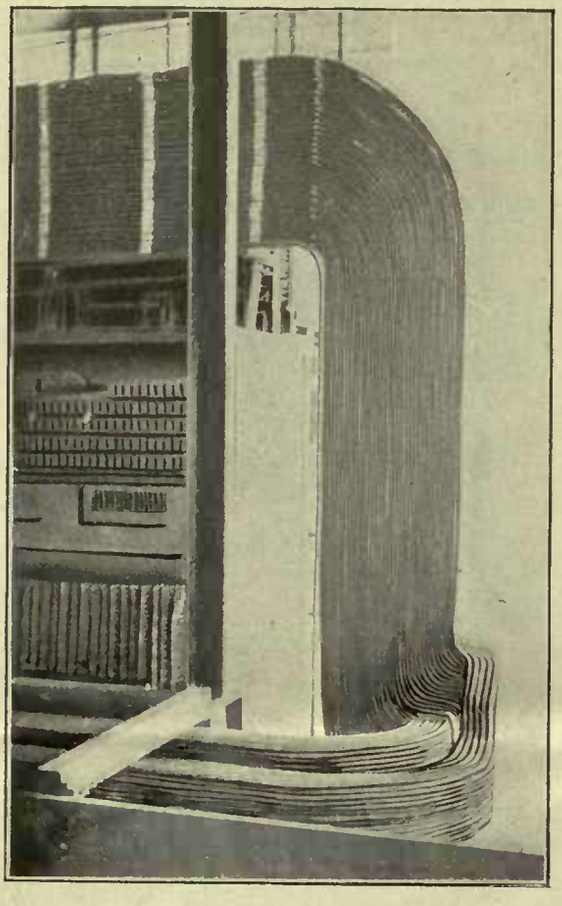

FIG. 18.—LINE CONSTRUCTION OLD ST. LOUIS EXCHANGE.

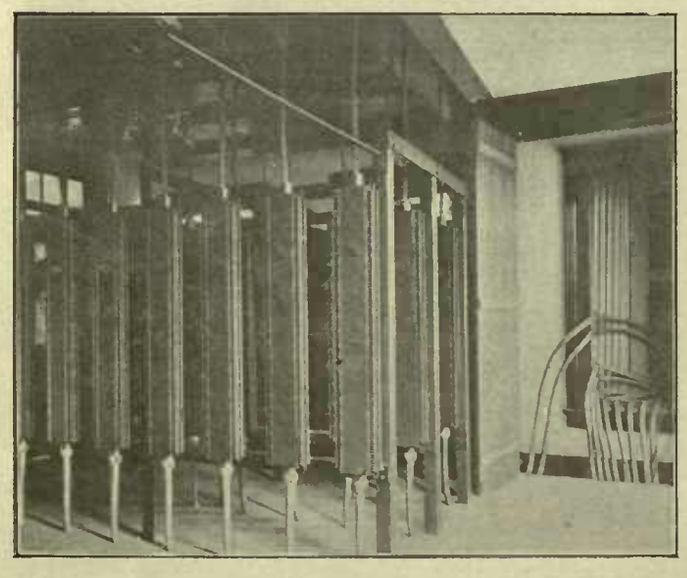

FIG. 24.—CABLE HEADS.

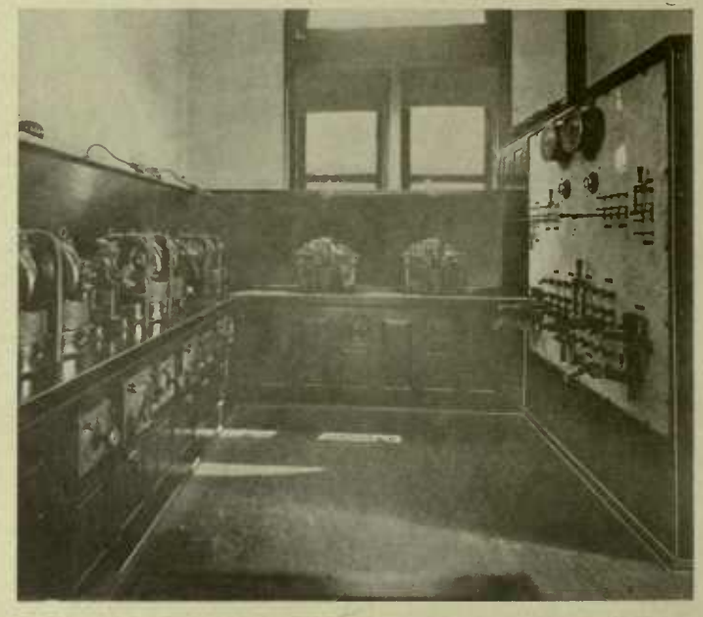

FIG. 19.—PITTSBURG POWER PLANT.

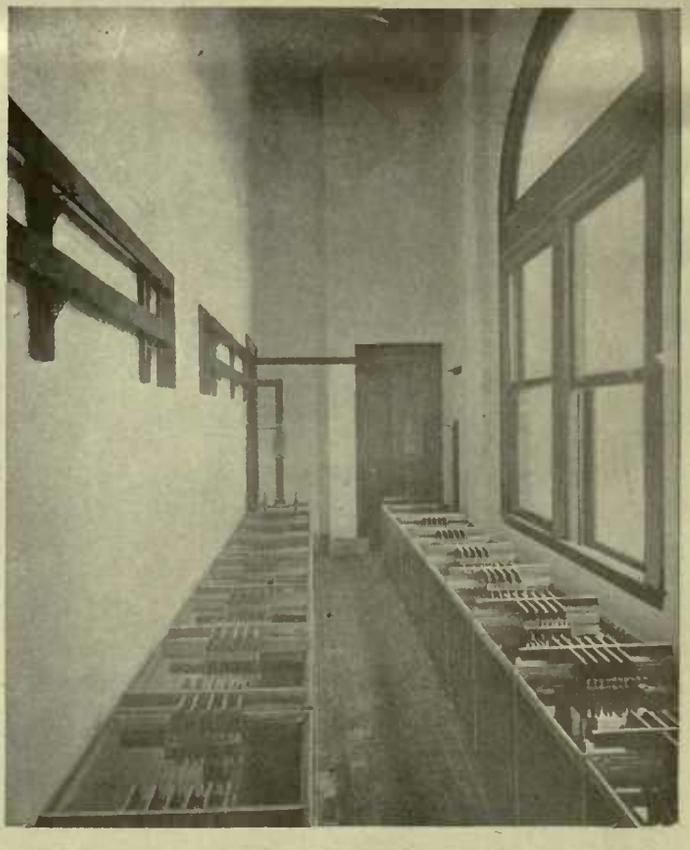

FIG. 20.—PITTSBURG STORAGE BATTERIES.

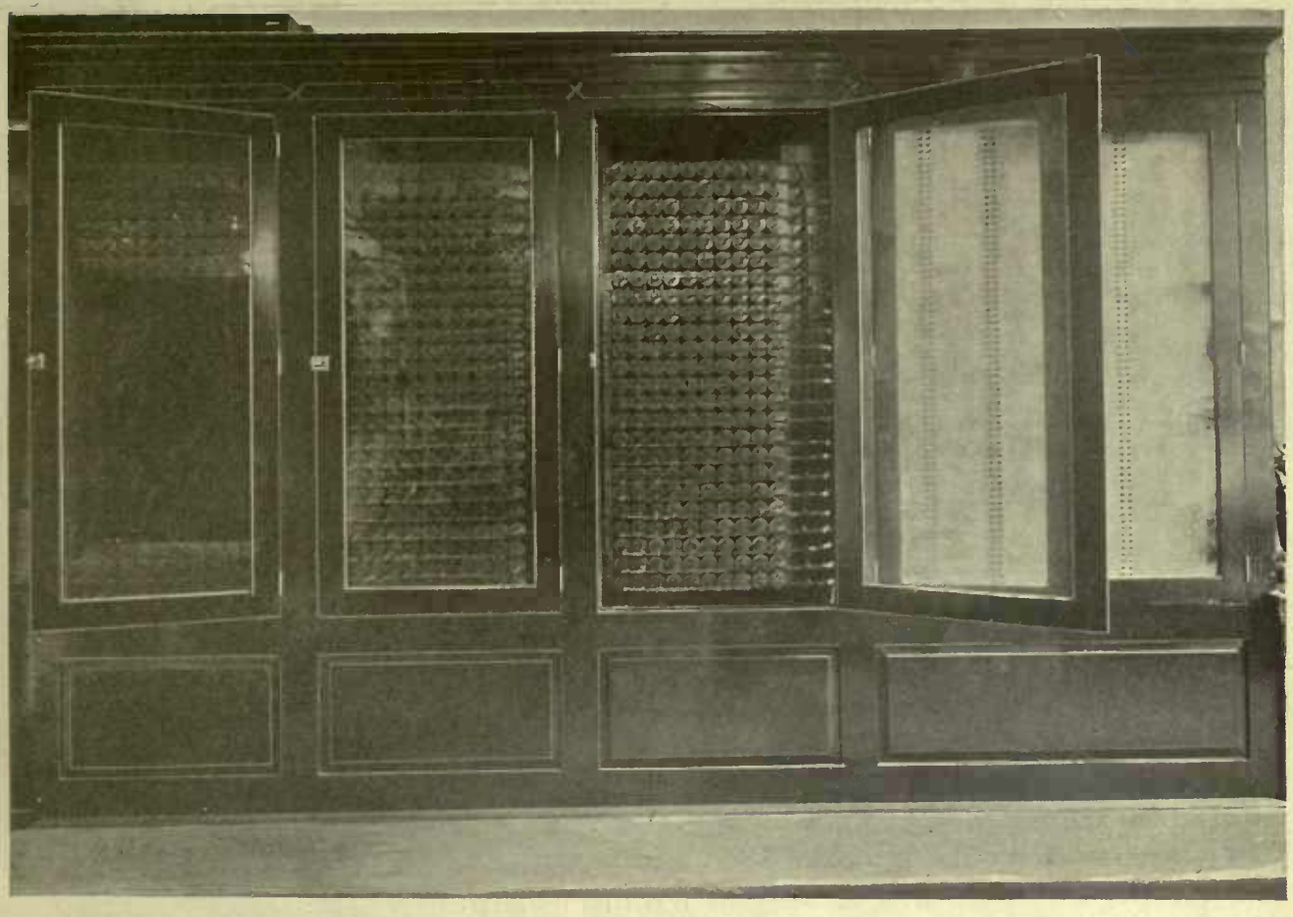

FIG. 21.—PITTSBURG REPEATING COIL RACK.

of general interest, and which, perhaps, will make some of the statements which I have made more clear to those not well posted in telephony. My first view in this series (Fig. 10) is that of the interior of the exchange installed by the Western Electric Company, at Paris, France. This board is next to the largest in the world, it having a capacity of something like 9300 lines.

The next view (Fig. 11) is that of the multiple board installed for the Pittsburg & Allegheny Telephone Company, of Pittsburg, Pa., by the Kellogg Switchboard & Supply Company. This board is now wired for 4080 lines and has an ultimate capacity of 6000. It forms the main office of the Pittsburg & Allegheny exchange, there being six branch offices located in the various parts of Pittsburg and Allegheny, all operating in conjunction with the exchange here shown. The total present equipment of these offices is about 7000 lines.

Fig. 12 shows the front view of one of the sections of the great switchboard at Paris, shown in Fig. 9. In this board mechanical annunciators of the electrically self-restoring type were used, which can be seen at the extreme top of the section. Those signals are automatically restored when the operator inserts a plug into the answering jack, but this arrangement has a marked disadvantage over the more modern form of boards wherein the line signals are located in the immediate vicinity of the answering jacks. With the drops, as shown in this section, the operator had first to look to the top of the section, fix the number of the signal

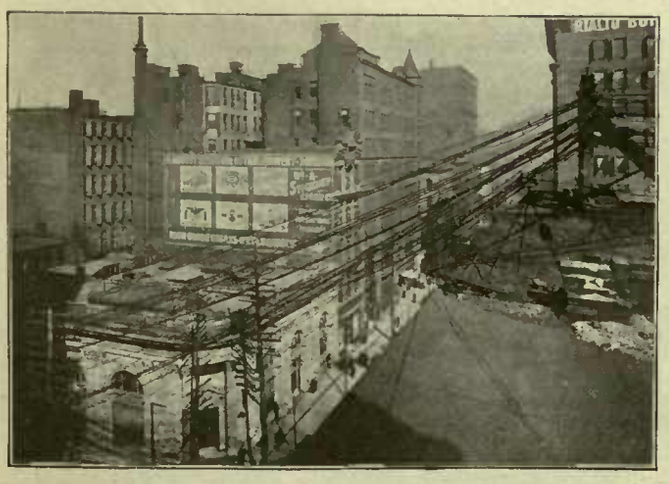

FIG. 22.—LINE CONSTRUCTION, OLD ST. LOUIS EXCHANGE.

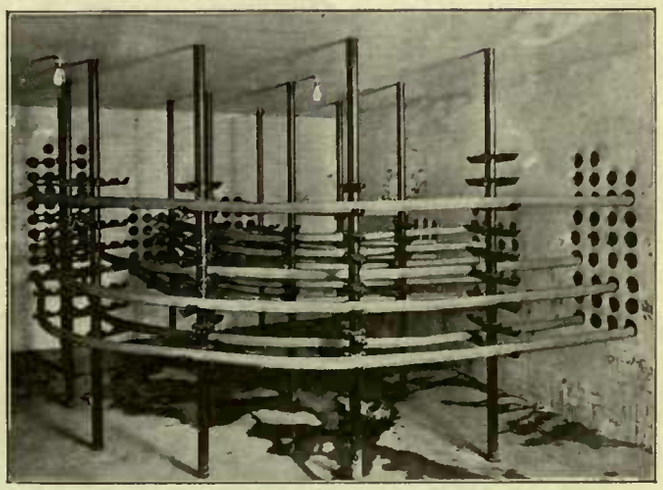

FIG. 23.—CABLE VAULT, ST. LOUIS EXCHANGE.

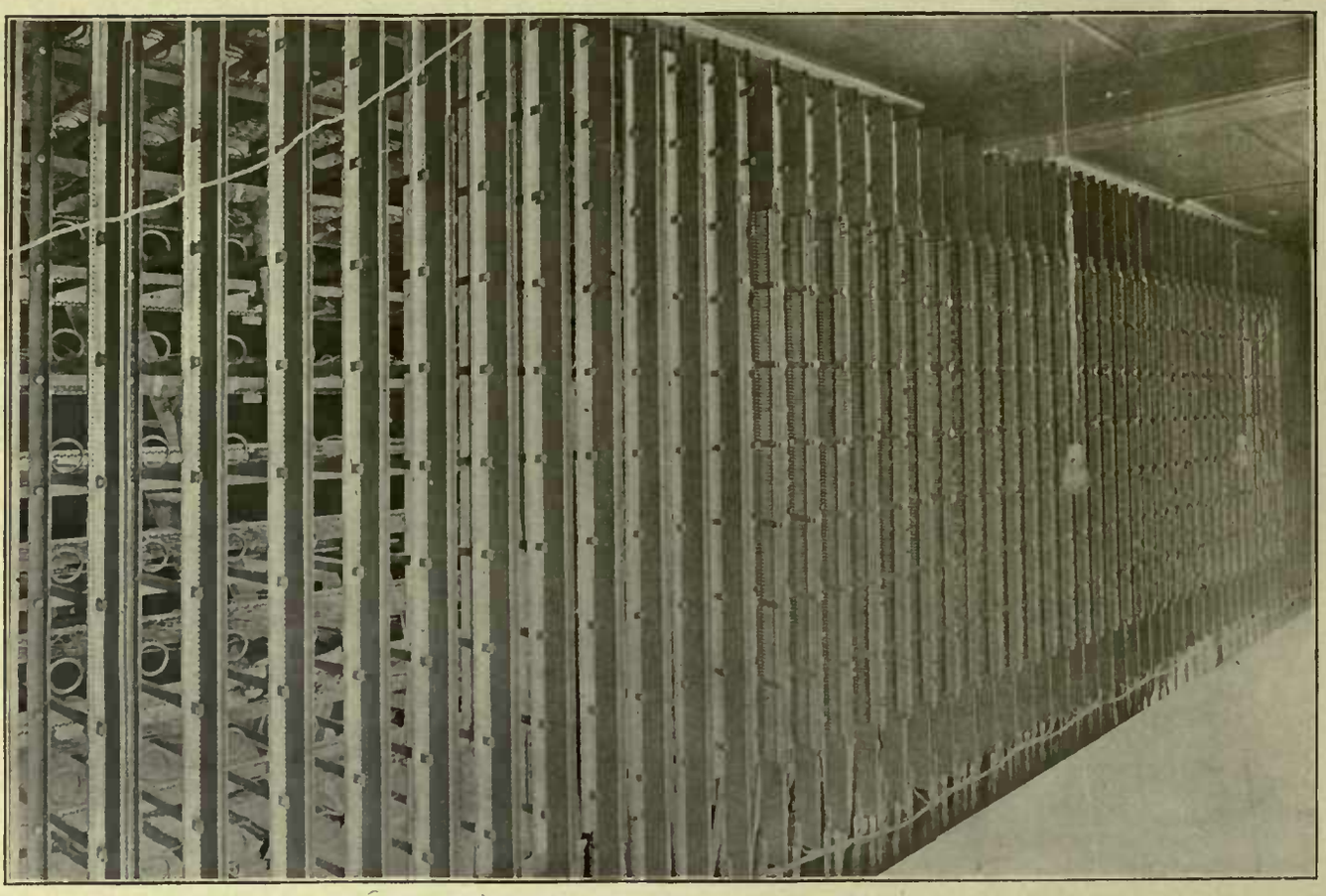

FIG. 26.—NEW ST. LOUIS DISTRIBUTING BOARD, NO. 1.

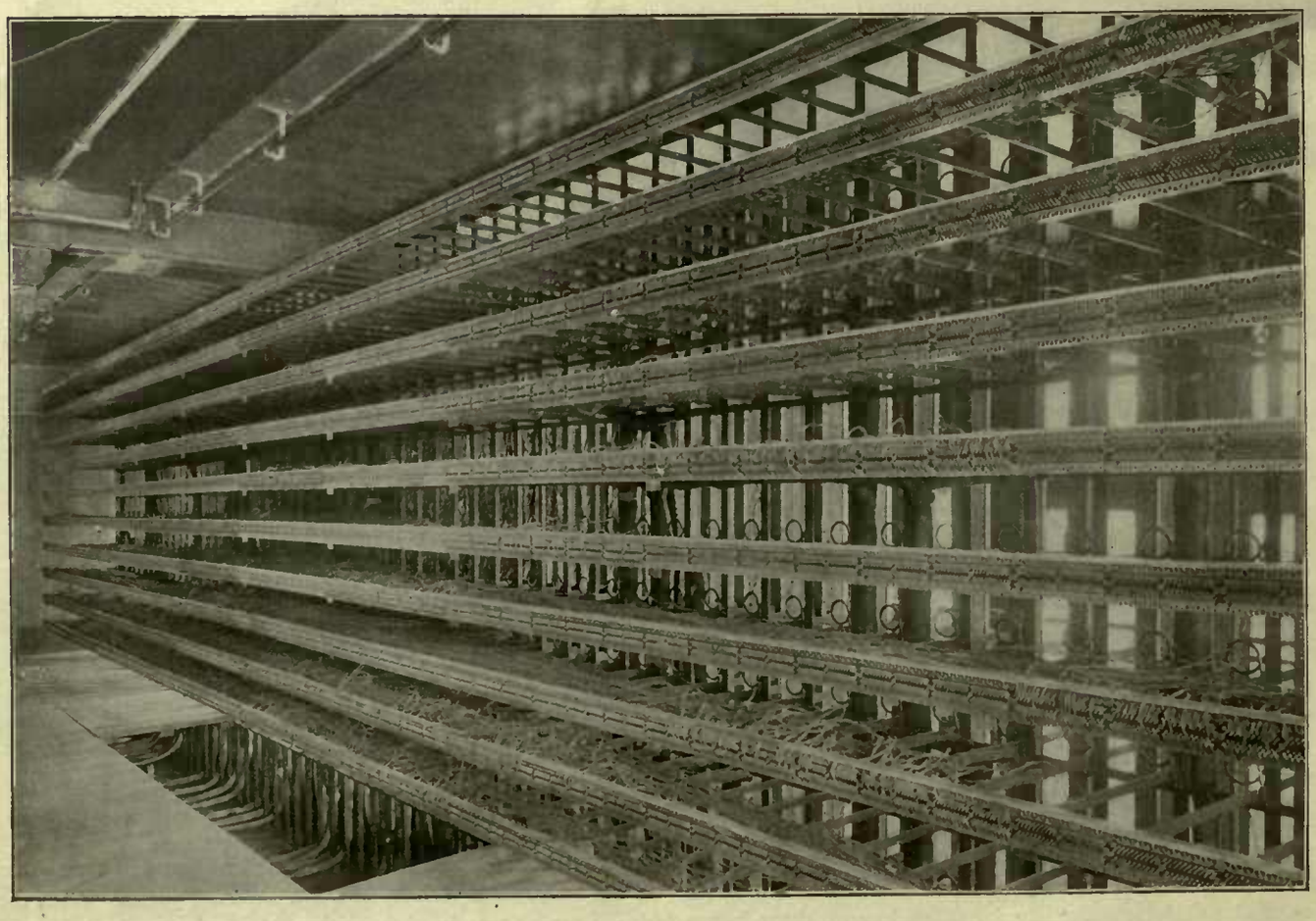

FIG. 27.—NEW ST. LOUIS DISTRIBUTING BOARD, NO. 2.

displayed in her mind, and then look down and pick out the corresponding answering jack in which to insert the plug. In the later boards, where the line signal is next to the corresponding answering jack, she is saved this change of vision, and also this mental operation. She simply plugs into the jack next to the signal displayed without any regard to its number.

In Fig. 13 is shown a front view of several of the sections of the Pittsburg exchange, a complete view of which

FIG. 25.—OLD ST. LOUIS DISTRIBUTING BOARD.

was just seen, and in Fig. 14 a closer view of one of the sections. Here the multiple jacks are plainly seen in the upper portion of the board, the answering jacks and line signals being shown below. One of the key shelves is raised, showing the wiring of the ringing and listening keys, and also the springs of these keys. Below this one of the front panels is removed, showing some details of the wiring of the connecting rack of the section.

The next view (Fig. 15) is that of the rear of the St. Louis switchboard. The cables leading to the multiple jacks are shown in the upper portion of this picture, and below them the cord racks, the supervisory relays and the running box containing the various line cables are clearly shown.

Fig. 16 is a similar view of the rear sections of the Pittsburg exchange, a good idea of the multiple cables being afforded.

Fig. 17 shows with greater detail the rear of one of the Pittsburg sections. The multiple cables are seen at the top and below these are the relay boxes, one of which is open, disclosing the supervisory relays at the top and the line relays of that particular position. In the lower portion of the picture is shown the connecting rack, to which all of the wiring of this particular section is led.

In Fig. 18 is shown the turning section of the multiple cables. This is at the end of the switchboard and shows where the multiple cables are turned downward into the running box, where they run along back of the sections, and are joined to their proper answering jacks and signaling circuits on the connecting rack of each section.

In Fig. 19 is shown what might be called the heart and lungs of a telephone exchange. This is the power plant of the Pittsburg & Allegheny exchange. On the right is seen the power switchboard, which is of marble, and is provided with voltmeters and ammeters, circuit breakers, and all switches necessary for handling the machines and batteries. In the center of the picture are shown the two ringing machines and on the right the charging machines for charging the storage batteries.

I will now show (Fig. 20) the storage batteries of this same exchange, these comprising ten cells each of chloride accumulator, each cell being of 800 ampere-hours capacity. The tanks are of wood, lined with lead, and the floor and walls are of tile laid in cement. At the upper left-hand portion of the picture may be seen the heavy copper bus-bars forming the discharge leads of these batteries. These are of solid copper, 3 ins. x ½ in. in thickness.

The next view (Fig. 21) shows the repeating coils of the Pittsburg & Allegheny system, there being one of these coils for each pair of cords in the entire exchange. These coils are iron clad and are enclosed, as shown, in a practically dust-proof cabinet. It is through these coils that the current from the storage battery is led to the various cord circuits, whence it passes to the lines of connected subscribers to furnish talking current.

No single feature of telephone work has shown greater advancement than that of outside line construction. In place of the overhead wire, so common a few years ago, and still too common, the lines in systems are being placed underground to a greater and greater extent. My next picture (Fig. 22) illustrates a piece of overhead construction, showing lines as they were about to enter the exchange of the old system at St. Louis, Mo. In marked contrast to this, the

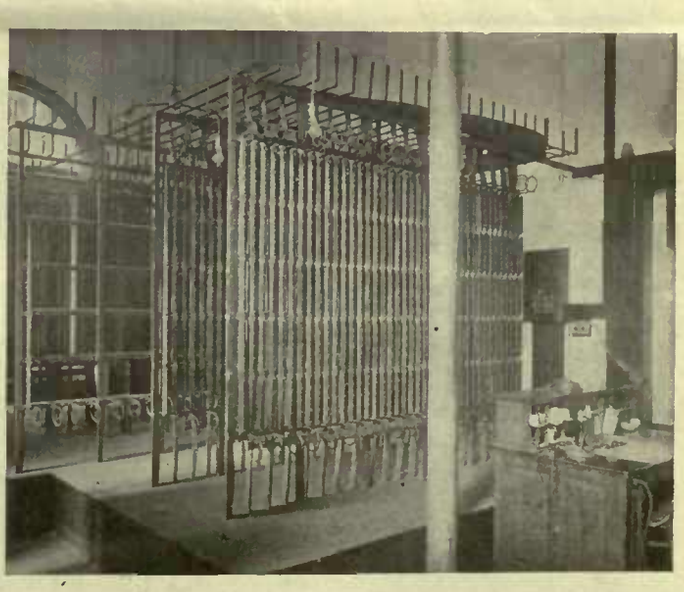

FIG. 28.—KELLOGG DISTRIBUTING BOARD.

next (Fig. 23) is a picture which shows how the subscribers' lines now enter the exchange building in that same St. Louis system. This is a picture of an underground cable vault and shows with what care and system the cables coming in from the street are led into the cable shaft leading to the exchange room.

The next view (Fig. 24) shows a common method of terminating the lines of telephone exchanges, or rather terminating the outside construction work. The line cables may be seen leading up from the lower part of the picture These enter the cable heads, which are, in this case, cast-iron boxes hermetically sealed, and the various wires of the

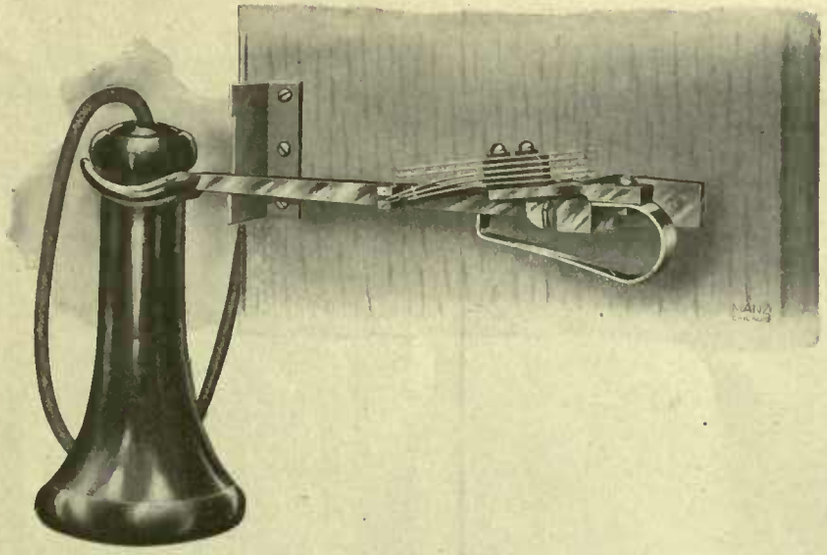

FIG. 29.—HOOK SWITCH (1).

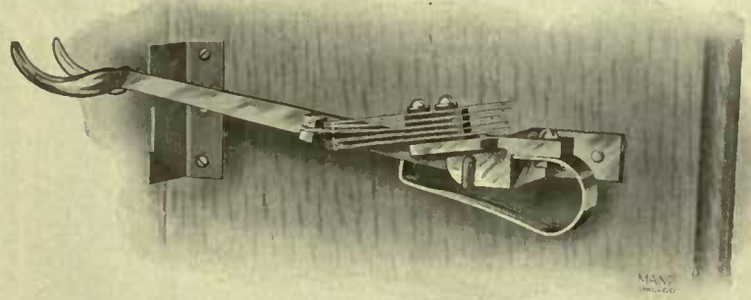

FIG. 30.—HOOK SWITCH (2).

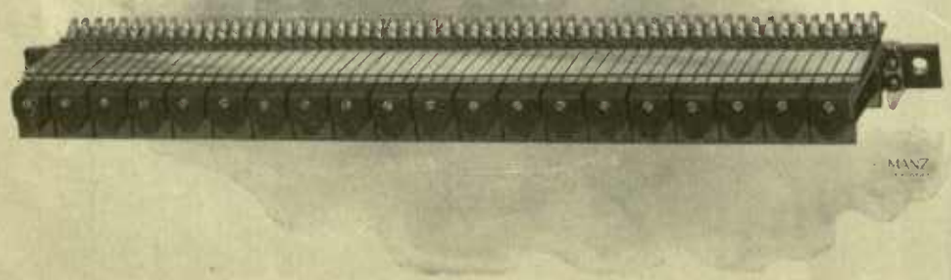

FIG. 31.—STRIP OF LINE RELAYS.

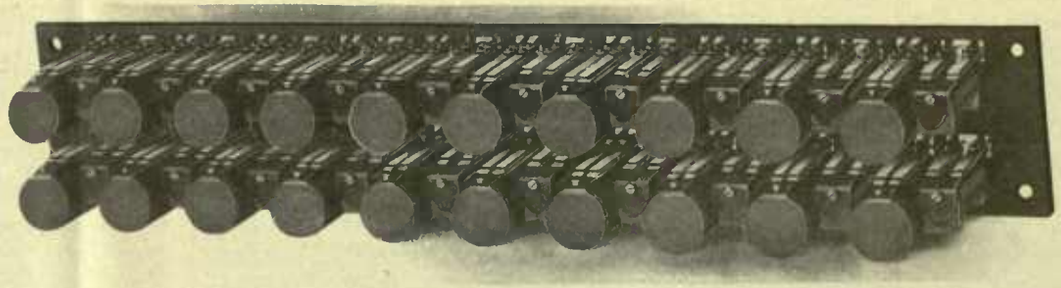

FIG. 33.—STRIP OF LINE AND CUT-OFF RELAYS (BACK).

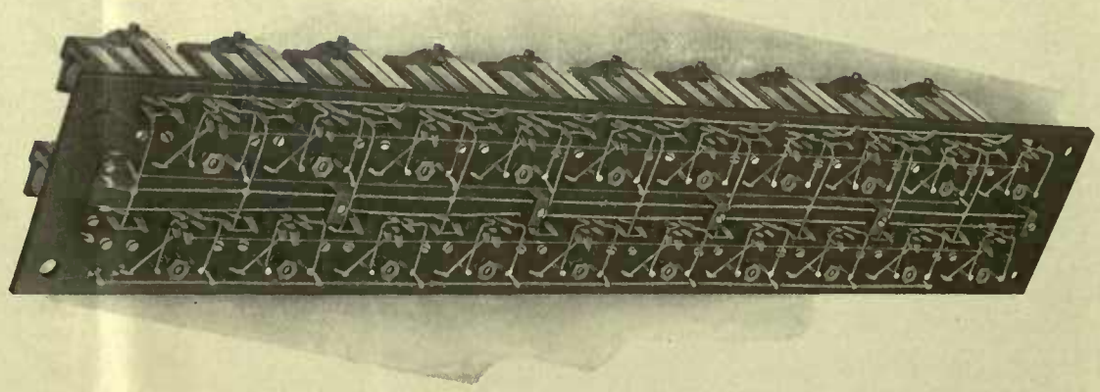

FIG. 34.—STRIP OF LINE AND CUT-OFF RELAYS (FRONT).

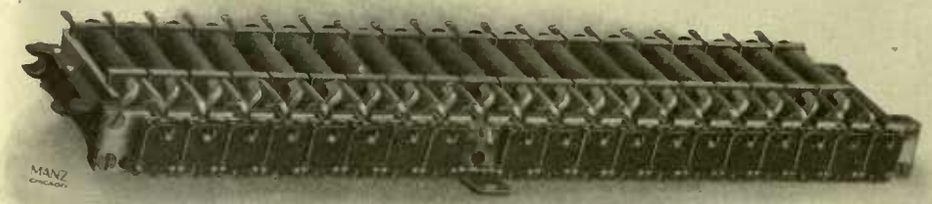

FIG. 35.—STRIP OF DROPS.

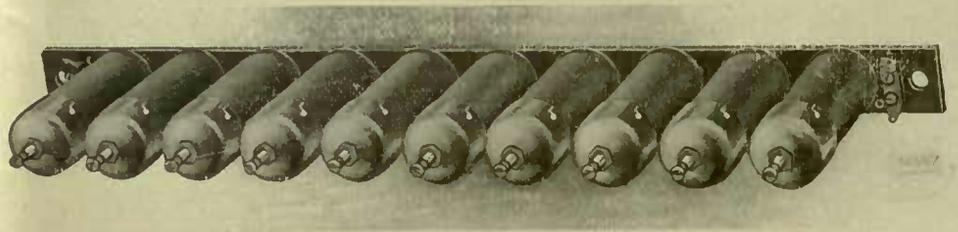

FIG. 39.—STRIP OF SUPERVISORY RELAYS.

cables are distributed to insulated contact points on the inside of the boxes. These contact points extend to the outside of the boxes through insulated bushings, and from thence the circuit is led through protecting devices, after which they are again arranged into cables which proceed from the top of the cable heads and are then led to the switchboard terminals.

This brings up the subject of distributing boards. A little thought will show that some means must be provided for distributing the various line wires which enter the exchange to their proper terminals on the switchboard, and to

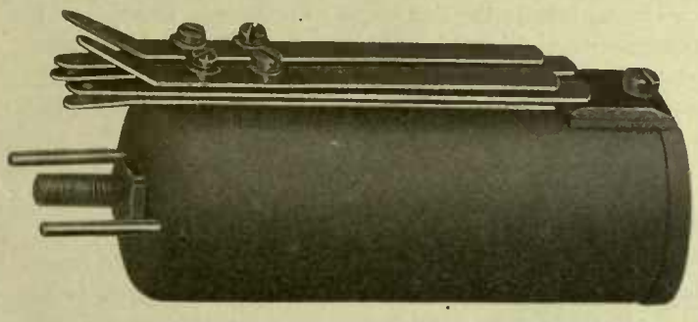

FIG. 32.—SINGLE CUT-OFF RELAY.

enable such changes to be made in this distribution as required. If such provision were not made and the line cables were run directly to the switchboard, the wires in one 100-pair cable being led, for instance, to the first position, and the wires in the second 100-pair cable to the second position, etc., it would be necessary at any time when a change in a subscriber's number was desired, to open the cable, take out the proper wire and fasten it to one of the other cables leading to the proper section of the board. The changing about of the various line wires from one part of the board to another is a very common occurrence, and to do it in the manner just suggested would be wholly impracticable. In order to provide means for systematically making such changes, recourse is had to what are called distributing boards or frames. These assume a great variety of forms, but the principle upon which they are designed is as follows: In one portion of the distributing board are placed clips suitably arranged, in which the wires of the line cables may terminate. On another portion of the distributing board is arranged another group of clips or connectors in which the separate wires of the switchboard cables may terminate. We thus have all connections from the lines, and also all connections from the switchboard wired in a permanent manner to the various connectors on the respective portions of the distributing board. The gap between the terminals of any pair of wires on the line side of the distributing board, and those of the corresponding pair leading from the switchboard is filled by means of bridle or jumper wires. The distributing board is so arranged that these jumper wires may be run from any pair of connectors on the line side to any pair on the switchboard side, and if the distributing board is a good one, these jumper wires are laid with perfect system and may be changed as often as desired.

In Fig. 25 is shown a distributing board which is happily a relic of the past, but which in its day was distinctly superior to others and may be said to have served its purpose well. This picture was taken from the inside of the distributing board which was in the form of a hollow square, one corner of which is shown. This accommodated about 4000 lines entering the old Bell exchange at the corner of Fourth and Pine Streets, in St. Louis. The line wires were practically all aerial and were brought to a large tower at the top of the exchange building; they were then led down in suitable cables, as shown in this picture, which cables were fanned out for attachment to the clips on the upper portion of the distributing board. In the same manner the switchboard cables were led up to the lower set of clips on the distributing board. Connection between any line wire and any switchboard wire was then completed by means of the jumper wires, as readily seen.

It is the object of modern distributing boards to do away with the confusion in these jumper wires and to lead them as far as possible in parallel directions in their courses from the line to the switchboard sides of the frames. My next view (Fig. 26) shows the switchboard side of the distributing board of the present main exchange of St. Louis, which exchange takes the place of the old exchange, the distributing board of which was just shown. The switchboard cables may be seen leading up from beneath. They are fanned out to the lightning arrester terminals shown on the right-hand portion of the board, these terminals being omitted from the left-hand portion, which latter portion is reserved for future growth. These arresters contain a

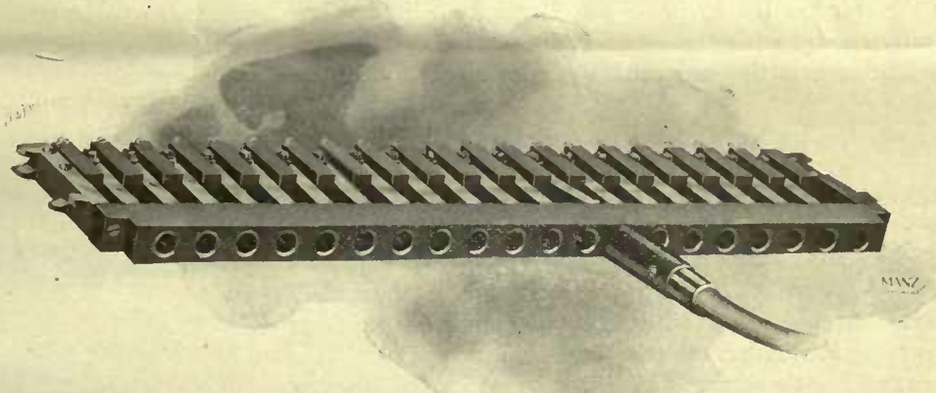

FIG. 37.—STRIP OF JACKS.

device which will open the line and ground it if an extraneous current of sufficient intensity to be considered dangerous comes in over the line. Such currents are termed sneak currents, and would do great damage but for these little protectors. The protectors also include static arresters, by means of which a high potential current is caused to jump to ground rather than go on through the intricacies of the switchboard. The jumper wires are led from the terminals on this side of the distributing board through iron rings, some of which may be seen at the extreme left of the picture and to the line side of the distributing board, a view of which (Fig. 27) is now shown. The terminals on this side are arranged in horizontal rows, and the jumper wires coming from the line side, after passing through their respective rings, are led up or down as the case may be, to the particular horizontal row on which the desired terminal exists, and are then led along the corresponding horizontal shelf to the proper terminal. The

cables leading in from the street are permanently connected to these horizontal rows of terminals and may be seen coming in at the bottom portion of the board through the trap door in the floor.

The next view (Fig. 28) shows a Kellogg distributing board, this particular one being that at the Pittsburg exchange already referred to. The peculiar feature of this board is that the line and switchboard terminals, instead of being arranged on opposite sides of the frame work, as on the board just described, are arranged on alternate vertical strips, there being a strip of switchboard terminals and then a strip of line terminals, and so on. The arresters in this case are put on the cable heads, which may be seen in the rear of the view. Jumper wires are led up or down from the respective line terminals through the large iron rings seen at the bottom and top of the board, and then horizontally to the proper strip of line terminals, and then up or down to the proper terminal on this. The cables from the cable heads in the rear are led up to the line strips from beneath, as clearly shown, while the cables leading to the switchboard may be seen in the iron running frame at the top of the picture.

FIG. 36.—STRIP OF LAMPS.

I have had a few slides prepared representing in detail parts of the apparatus used in some of the latest Kellogg exchanges. I show here (Fig. 29) a subscriber's automatic switch-hook with the receiver upon it. The next picture (Fig. 30) shows the same hook with the receiver removed. It will be seen that the long lever serves to bend the central spring into engagement with the lower or upper set of springs according to whether the telephone is in use or not. This accomplishes the changes of circuit by which the operator is automatically called and by which she is later given the signal to disconnect, which changes are made, of course, entirely without the volition or knowledge of the subscriber.

Passing on to the central office, I will show (Fig. 31) a strip of line relays similar to the ones used in the Pittsburg exchange. These relays are mounted twenty per strip, as shown.

The next cut (Fig. 32) shows a single line cut-off relay. The magnet of this is enclosed in an iron shell which forms a portion of the magnetic circuit. The armature of this relay, when attracted, causes the two long springs to break contact with the lower springs, and to make contact with the two upper springs. I may say, in passing, that all contacts in the best relays of this description are made of platinum. These relays are about 1¼ ins. in diameter, and the shells are of soft iron about ⅛ in. thick.

In the latest Kellogg exchanges the line and cut-off relays are mounted side by side on the same strip. This view (Fig. 33) shows such a strip containing twenty of each relays, the line relays being the smaller of the two. The strip represents a unit of twenty lines, which unit is carried throughout the entire scheme of wiring in the central office. The next illustration (Fig. 34) shows the opposite side of this relay strip, showing the connecting wires from the various terminals. These terminals pass through walls in the iron mounting strip and are readily accessible for soldering in the wires. In mounting the line and the cut-off relay in such close proximity, many of the wires which would otherwise have to be formed up in cables are reduced to the short, stiff bare wires clearly shown in this picture.

Coming now to the line signals themselves, in Fig. 35, I show a strip of drops, these being mounted on ½-in. centers so as to correspond to the spacing of the jacks. These were used before the adoption of the line lamp signals by the Kellogg Company, a strip of which signals is shown in Fig. 36. This strip is formed from a single piece of hard rubber about 10 ins. long and ½ in. thick. The lamps, one of which is shown in the front of the view, are so arranged as to slide into their sockets between the jack springs in such manner as to make the proper circuit connections. In front of each lamp is a little lens, usually of opalescent glass, this lens being carried in a spun brass cap. The advantages of the line lamp signal over the old form of mechanical signal is obvious, the principal ones being the absolute freedom from complexity, cheapness, and the fact that they may be removed instantly if found defective and replaced by good ones. A defective line lamp may be taken out and another one substituted in less than one-half minute. Another beauty of the line lamp is that when it is out of order it may be thrown away, which is much easier than repairing a mechanical drop. These lamps usually operate at 20 or 24 volts, take about ¼ ampere and give approximately ⅓ candle power. The calculated life of these lamps, with their present degree of perfection and with the average rate of use, is about thirty years, but, of course, this figure remains to be verified by actual service, for unfortunately the telephone business is not yet old enough to prove the statement.

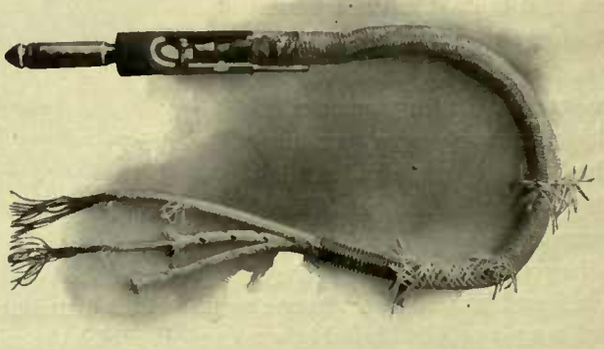

FIG. 38.—CORD AND PLUG IN SECTION.

I now show (Fig. 37) what is by all odds the most important piece of apparatus in a telephone exchange—the spring jack. This is a strip of the two-point jack already referred to, and it will be seen that they are mounted twenty to a strip on spaces corresponding to those of the lamp jack. The

same jack is used for both answering and multiple. This strip is built up of hard rubber, brass and German silver, the front being a solid piece of hard rubber, slightly over 10 ins. long, and drilled for receiving the sleeve contacts. The rear of the strip is a piece of hard rubber milled to receive the line springs and the rearwardly projecting lugs from the sleeve contacts. This rear strip is reinforced by a heavy brass strip, into which the screws holding the line springs are threaded. In this particular strip the jacks are on ½-in. centers, the strip being 7/16 in. high. The spacing with this same construction is readily reduced to ⅜ in. Where a smaller spacing than this is required, as in a board of extreme size, a somewhat different construction would be used.

I have spoken throughout the evening of cords and plugs, with the details of which some present may not be familiar.

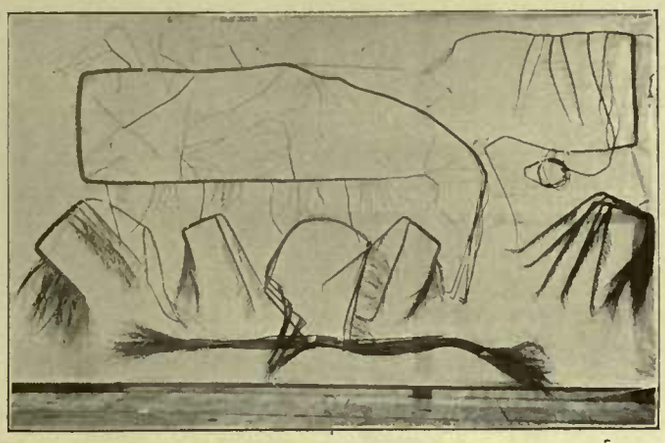

FIG. 40.—CABLE FANNED OUT.

The next picture (Fig. 38) shows one of each, the plug being cut away to expose the method of attaching the cord, the cord having its various layers removed to better show its construction. This plug has two contact points instead of three, as described in connection with Western Electric or Bell system. It will be noticed that the two strands of the cord are composed of twisted tinsel, over which a wrapping of floss silk and a braid of cotton are placed. Thus insulated, the two conductors are bound together by a wrapping of cotton, after which they are enclosed in a spiral of brass wire for protection. Over the spiral of wire are placed two layers of linen braiding throughout the entire length of the cord, and for about 10 ins. back of the plug a third reinforcing layer is put on. These cords vary in length, according to the size of the multiple board, this length being anywhere from 36 ins. up to nearly 100 ins.

The next view (Fig. 39) shows a strip of ten supervisory relays, these relays being the ones used in connection with the cord circuit for controlling the supervisory lamps. These are iron clad, being made in the same shell as is used for the cut-off relay. The armature, a disk of iron about 1¼ ins. in diameter, is suspended in front of the poles of the electromagnet by a thin leaf spring. The working parts of the relay, including the armature and contact points, are enclosed in a brass cap, which cap locks on the shell with a bayonet joint.

The next and last view (Fig. 40) shows a few of the cables used in switchboard work, as they are formed up in the factory. Some of these are made from standard 21 and 41-pair cables in long lengths with their ends formed and laced to fit the particular portion of the switchboard for which they are required. Some of the other cables are formed by hand, exactly as shown, directly from the insulated wire, which is usually twisted in pairs. These cables, as you will see, remind one more of diagrams of nervous systems, sometimes seen in medical books, than anything else I can think of.

The design of telephone switchboards and apparatus is a matter requiring attention to almost infinite detail. Besides having a knowledge of the requirements of telephone service and a thorough appreciation of the engineering problems involved, the designer must have a peculiar faculty, which has been termed "telephone sense." Ability to distinguish between apparatus and circuits that will work successfully in practice, from those that will work only in the laboratory, is not acquired by all; and the problems are so remote from those of other branches of electrical engineering, that it is seldom that precedent taken from other branches can be found.

Those who have the best interest of the telephone business at heart are now designing their apparatus and circuits on the basis that telephone systems in small villages must have as good transmission as those in the largest cities, with the idea in view that in the future the whole continent will be one vast telephone exchange, the various large cities being the main offices, and the long-distance lines, the trunk lines between them, and the small villages the branch exchanges.

I regret that time, together with a lack of definite information, prevents me from treating of Dr. Pupin's recent invention, but this subject is one of such apparent importance, that to devote less than a whole evening to it would be to do both the inventor and the audience an injustice.

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